4-19-2017

# Brewer's Spent Grain to Xylitol & Polylactic Acid

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# Brewer's Spent Grain to Xylitol & Polylactic Acid

**Abstract**
With this project, the authors seek to present a desirable and novel process for converting brewers' spent grain into two value-added products: the alternative sweetener, xylitol, and a biodegradable plastic, polylactic acid. This particular process is based in the Philadelphia Naval Yard, and uses the spent grain from surrounding breweries and microbreweries as its input. However, while the collection logistics and input quantity may change, the process is one that may be implemented anywhere, with varying degrees of success.

The process consists of collection, universal pretreatment, then a split to feed one of two continuous fermenters. A highly acidophilic strain of the yeast *Candida tropicalis* ferments xylose into xylitol, which is then purified and pelleted in a marketable state. *Lactobacillus delbrueckii* bacteria ferments glucose into lactic acid, which is then polymerized to form polylactic acid of the desired molecular weight. This polymer is then purified and processed for sale. This product profile is optimal, as it incorporates both of the major constituents of the grain – cellulose and hemicellulose.

Under the current market conditions, this process is expected to be financially desirable. We estimate a return on investment of 25.5%, with an internal rate of return of 30.95% and a net present value of $34.5M by 2032. However, if the price of polylactic acid were to rise, as market patterns suggest it may, this process could quickly become even more profitable. We therefore recommend pursuing the proposed process, and possibly expanding to other densely populated areas.

**Disciplines**
Biochemical and Biomolecular Engineering | Chemical Engineering | Engineering

University of Pennsylvania School of Engineering and Applied Science
Department of Chemical and Biomolecular Engineering
220 South 33rd Street
Philadelphia, PA 19104

Dear Dr. Diamond and Dr. Vrana,

The following report contains the proposed design for a processing facility of xylitol and polylactic acid from brewer's spent grain, as specified in the problem statement provided by Dr. Diamond. The processing facility has an input of 275,000 barrels (about 59 million kg) per year of spent grain, all collected in the Philadelphia area and brought to the facility in Navy Yard. The spent grain is washed with an acid pretreatment and the broken-down hemicellulose is sent to a xylitol fermenter, while the cellulose is broken down with ammonia and sent to a lactic acid fermenter. The xylose is fermented using *Candida tropicalis*, and the aqueous xylitol is purified with two ion exchange columns and later crystallized into final pellet form. The glucose is fermented using *Lactobacillus acidophilus*, and the L-lactic acid produced is transferred to a diphenyl ether solvent and converted to polylactic acid via a direct condensation polymerization reaction over a tin oxide catalyst. A combination dichloromethane and methanol treatment is used to crystallize the polylactic acid out of solution in a marketable form.

The report contains a highly-detailed design of this process, along with a profitability analysis and other important considerations. The designed process is able to produce 3.6 million kg/year xylitol and 3.9 million kg/year 79,000 MW polylactic acid when the plant operates 24 hours a day for 330 days a year. The current design requires $46.0 million total capital investment. The annual sales at this production level are $90.0 million, however with large annual operating costs the net earnings for this design are roughly $20.0 million per year. The process has an estimated ROI of 43.3% and IRR of 28.4%. The NPV by 2032 is estimated to be $80.5 million.

Based on this analysis, our group believes that this facility is economically feasible. Several policy issues, including increased FDA regulation on spent grain as animal feed, could alter the economic forecast of this design. We recommend pursuing this plant design as outlined with continued research on charging disposal costs to breweries and lowering fermenter media costs by recycling cell debris.

Sincerely,

| Anthony Carradorini | Nabila Faour | Alexander George | Kelsey Simet |
|---|---|---|---|

# Brewer's Spent Grain to Xylitol & Polylactic Acid

*Alexander George | Kelsey Simet | Anthony Carradorini | Nabila Faour*

Project Submitted to Dr. Bruce Vrana and Dr. Warren Seider

Project Proposed by Dr. Scott Diamond

Department of Chemical and Biomolecular Engineering

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University of Pennsylvania

April 18, 2017

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# 1.0 Abstract

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Under the current market conditions, this process is expected to be financially desirable. We estimate a return on investment of 43.3%, with an internal rate of return of 28.4% and a net present value of $80.5M by 2032. However, if the price of polylactic acid were to rise, as market patterns suggest it may, this process could quickly become even more profitable. We therefore recommend pursuing the proposed process, and possibly expanding to other densely populated areas.

# 2.0 Introduction

## 2.1 Background Information

Spent grain is a valuable byproduct of the brewing process. It is a solid residue that results from the production of malt after grains are soaked in water, germinated, and dried. Spent grain is collected during lautering at the end of the mashing process. It is generally constituted by lignin, cellulose, hemicellulose, and protein, though its composition variability depends on the type of grain used, processing conditions, and preservation method [1].

Spent grain can be as much as 85% of a brewing process's total byproduct and has been widely used for livestock feed due to its high fiber and protein content. It also has a high water content, making the wet grain a very perishable and bulky product that is difficult and costly to distribute. Therefore, it is mostly transported to farms in the vicinity of the brewery [1]. Most micro to medium sized breweries give their grain to farmers at no cost in return for the farmers picking up the grain on a regular schedule [2]. If the grain is not disposed of within 1-2 weeks, wet grain degradation becomes a great burden, particularly for smaller breweries without sufficient storage space or preservation means. In general, the spent grain is given to local farms free of charge or at a very low price to guarantee it can be removed from the plant before degradation. Overall, many breweries regard their spent grain as burdensome.

In 2013, the FDA proposed a rule as part of its Food Safety Modernization Act with the aim to regulate and improve safety of animal food, and thus prevent foodborne illness in animals and humans. Despite facing vast opposition by breweries and farmers, the rule was finalized and became effective in 2016. It outlines good manufacturing practice and hazard analysis that must be followed to ensure products can be ruled safe to constitute animal feed. The system enacted includes chemical or physical hazard identification, preventative controls, and recall plans [3].

This rule has added to the burden faced by breweries to dispose of their spent grain. Our project is capitalizing on this unique situation, and looks to find a profitable use of this bulky byproduct.

Alternative applications of spent grain such as biofuel and bioproduct production can be a viable and cost effective option for breweries since they would not incur extra costs to comply with the Food Safety Modernization Act. A main concern for breweries is securing a weekly pickup schedule to reduce the risks of grain degradation and avoid preservation costs. Our project established a pickup schedule with multiple breweries in the Philadelphia area, as outlined in the logistics section.

Our initial product selection consisted of a preliminary market and profitability analysis to determine which products could provide the most profit for a given feed volume. The three main products considered were xylitol, polylactic acid (PLA) and bioethanol. Once the expected yields of each product were estimated, we performed a market analysis to choose the best two products. This analysis relied on the current market price, historical price data, demand trends, and future price projections for each of the possible products. Estimates obtained from this initial analysis, outlined in the market assessment section, motivated our choice of xylitol and PLA.

The process was designed to optimize total production of each product. The main steps outlined in the process include an acid or alkaline pretreatment to remove lignin, an enzymatic hydrolysis to extract the fermentable sugars, fermentation of sugars using different microorganisms, separations, and additional processing to a final packaged commercial product form.

## 2.2 Objective Time Chart

| | |
|---|---|
| **Project Name** | Bioprocessing with Brewer's Spent Grain |
| **Project Advisors** | Dr. Scott Diamond, Dr. Bruce Vrana |
| **Project Leaders** | Anthony Carradorini, Nabila Faour, Alexander George, Kelsey Simet |
| **Specific Goals** | Develop a processing plant for converting all available brewer's spent grain in the Philadelphia area to produce two products, and perform economic analysis to determine profitability of the plant. |
| **Project Scope** | In Scope:<br>1. Determine most profitable products to be made from brewer's spent grain (BSG)<br>2. Calculate amount of BSG available in Philadelphia area and establish collection logistics<br>3. Design processing plant for converting BSG to xylitol and polylactic acid (PLA) using a continuous process while adhering to good manufacturing standards<br>4. Perform economic and profitability analysis to determine if this business model is feasible<br><br>Out of Scope:<br>1. Manufacturing of biofuel from BSG<br>2. Use of genetically modified organism *Candida tropicalis JY* to increase xylitol product yield<br>3. Scaling of production process for other urban areas |
| **Deliverables** | 1. Mass and energy balance of system<br>2. Detailed flowsheet and Aspen model with simulation results<br>3. Fermentation kinetics and results<br>4. Equipment specifications and cost analysis<br>5. Profitability analysis with economic forecast |
| **Timeline** | Process design and profitability analysis to be completed by April 11th, 2017. |

## 2.3 Innovation Map

The innovation map for this project is presented below. Our process combines research on applications of spent grain to produce xylitol and PLA. Our group was able to innovate a method to simultaneously produce xylitol and PLA with maximum yields of both products. This was accomplished by determining a single sulfuric acid pretreatment step for all of the feed spent grain. This acid hydrolysis step breaks down all of the hemicellulose, which later ferments to xylitol, but does not affect the cellulose, which is crucial for making lactic acid. It is then simple to separate the liquid, broken-down hemicellulose to the xylitol fermentation path and the solid cellulose to the lactic acid fermentation path. If this single pretreatment step was not used, the feed spent grain would need to be initially divided into xylitol and PLA paths, which would lead to wasted hemicellulose and cellulose, depending on the path. Additionally, combining the first spent grain wash step with the initial spent grain acidic pre-treatment allows us to combine two separate unit operations into a single step, and therefore reduce costs for the process.

Other innovations include using more efficient microorganisms, adapting the usual batch fermentations to continuous, and combining unit operations into a single step to reduce costs. The replacement of the *Candida guillermondii* with *Candida tropicalis* and that of *Lactobacillus acidophilus* with *Lactobacillus delbrueckii* allowed our process to obtain high product to consumed substrate ratios of 0.87 and 0.99, respectively. One benefit of *C. tropicalis* is that it works best at optimal pH conditions of 2.5, which reduces the amount of base needed during the neutralization steps.

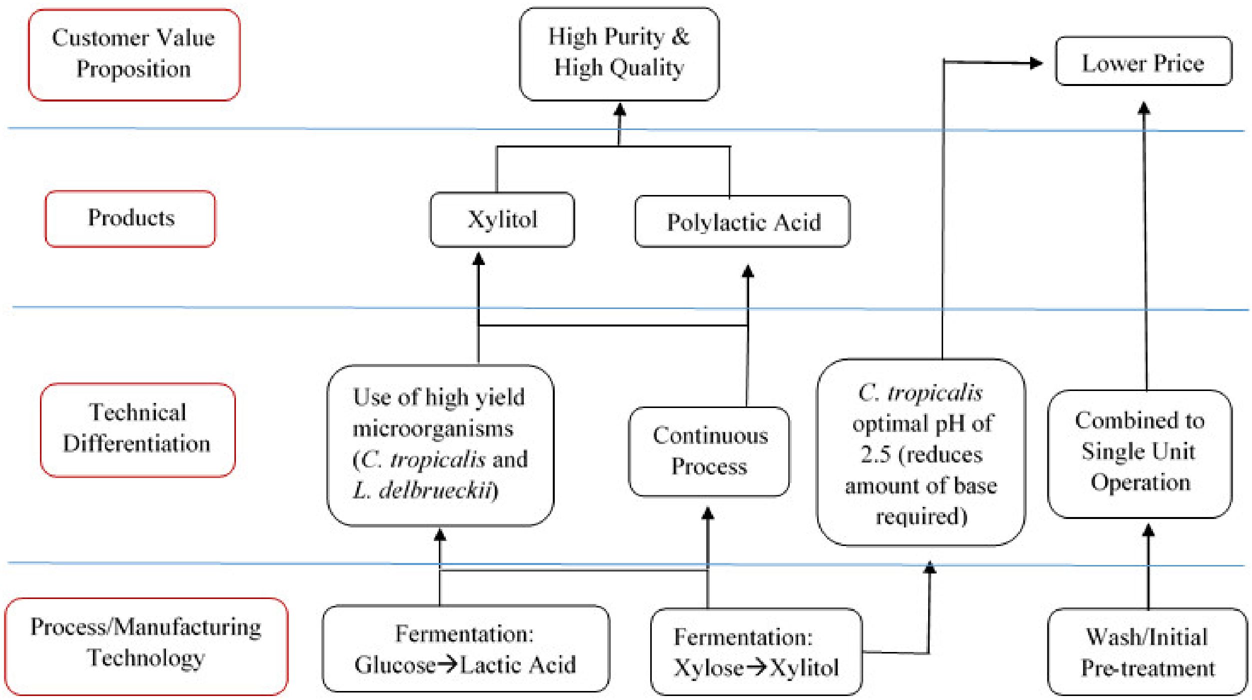



*Figure 2.1 - Innovation map showing important design decisions to optimize the process, including a crucial pre-treatment step and choice of high-yield microorganisms.*

# 3.0 Market Assessment for Spent Grain Collection and Products

### 3.1 Spent Grain Market

The price of spent grain is highly variable, as it is dependent on production scale, size, and location of a brewery. The majority of breweries give their spent grain to farmers at no cost, as the spent grain is a heavy, cumbersome byproduct that requires large storage space. It is reasonable to assume that any spent grain that our project obtained from from microbreweries and medium-sized breweries would be given at no cost, as long as the pickups are regularly scheduled at convenient times. After speaking with many Philadelphia-area breweries, our group found that up to production of about 10,000 kg/week, the spent grain is hauled away at no cost.

However, the majority of *volume* of spent grain produced by breweries is sold for a relatively low price to large-scale farms. The large breweries who produce more than 10,000 kg/week typically use a commodities broker to sell their grain. This grain is brokered to larger farms, who may mix the grain with other traditional feed. However, the price of this grain is extremely low. Due to low availability of price data from large-scale breweries, our group is not accounting for this cost in our process design.

The FDA's Food Modernization Act of 2014 greatly affected the market for spent grain, and additional drastic measurements are expected in the future. The act, in an attempt to control and prevent food-borne diseases, increased regulation of spent grain used as animal feed. However, the brewing industry was able to lobby against many of the stricter rules, creating some exemptions for alcohol distilleries. Still, any grain being sold as animal feed must have regular nutritional analysis work to monitor protein content. In Philadelphia, only two breweries are large enough to warrant selling their grain to farms. Due to the smaller size of area breweries and the projected increase of regulation, our group is working under the assumption that all spent grain would be provided free of charge. For this project, we only considered the cost of transporting the spent grain.

### 3.2 Product Market

The three possible products explored were xylitol, polylactic acid (PLA), and bioethanol, as recommended by the problem statement. The market analysis and competitive assessment ultimately lead to the product choices of xylitol and PLA. The market analysis estimated revenue less the cost of main inputs. While it was not an accurate predictor of profits, our group could roughly determine our market cap of each product and potential revenue.

*Ethanol*

Among the products suggested by the problem statement was bioethanol. Most bioethanol is currently produced from corn in the Midwest of the United States. It has enjoyed much market success in the past because of its renewable nature, low carbon emission, and use as a high octane gasoline additive. Spent grain has a high cellulose content, making it a reasonable feed for ethanol production, with much literature written on the process.

However, upon market analysis, it was found that the market for bioethanol has been stagnating in recent years. Interest has shifted to biodiesels, leading to less profitability in bioethanol production [6]. Also, its status as a commodity chemical has decreased the value of bioethanol, reaching a current market price of $1.46/gallon. Using an approximate feed amount of spent grain, the yearly production of ethanol was determined by assuming the available cellulose was converted by the fermentation yield of ethanol. The estimated production of 1.4 gallons/year places our sales revenue at $2.1 million. This amount of production would place our company at a miniscule market share – this level of production is approximately 1.4% of all bioethanol made in the Tri-state area. Our initial input costs of about $300,000/year consisted mainly of the cost of 2500 tons of NaOH/year purchased at a market price of $125/ton. The preliminary profit for ethanol through this process would be $1.8 million/year. Given that the analysis did not account for equipment, installation or energy costs, the overall total cost of production would make this selection unprofitable. Since the process cannot yield bioethanol at sufficient scale to make its production lucrative, we have opted to not produce this product.

*Xylitol*

Xylitol is a polyhydric alcohol that can be used as a low calorie substitute for sugar. It contains about 40% less calories than sugar given its lack of reducing groups. The increasing demand for low calorie sweeteners and diabetic care products is expected to drive an increase in the xylitol market. Its equivalent sweetness to sugar, along with its minimal effects on blood sugar and insulin levels, favor its increasing demand. The largest application of xylitol is in the chewing gum industry, generating over $450 million in 2015 [7]. Its use in beverage and bakery products has caused a 7% increase in its application in the food industry. Food applications of xylitol are expected to contribute to at least a $45 million revenue in the United States by 2023. The overall xylitol market is expected to generate about $1.12 billion by 2023 [8].

An estimated 1.9 million kg of raw arabinoxylan per year is available in the spent grain. The 0.87 yield of *C. tropicalis* allows us to theoretically produce 2.5 million kg of xylitol/year, sold at its current market price of $10.00/kg. The preliminary estimated inputs of 500,000 kg of sulfuric acid purchased at a market price of $0.13/kg and an inoculation of *C. tropicalis* cells purchased at $290/inoculation sets our raw materials cost at $64,710/year. The preliminary profit estimate for xylitol, not including equipment, installation, or energy costs, is $24.9 million/year.

*Polylactic Acid*

Polylactic Acid is a biodegradable plastic with applications across industries such as packaging, biomedical, transportation, electronics, agriculture and textile [9]. Packaging accounted for 59.6% of the overall market in 2013, and it is expected to remain the main segment for PLA. Its popularity in the packaging industry is due to the lack of emission of toxic gases upon incineration and properties such as durability and transparency. The market for textiles is also predicted to grow at a rate of 17.5% in terms of revenue by 2020 [10].

The estimated 5.6 million kg of cellulosic sugars available per year, along with the 0.99 yield of *L. delbrueckii*, allows us to produce about 5.5 million kg/year of lactic acid. Our sales revenue would be $82.5 million/year, assuming a 1 to 1 conversion of lactic acid to PLA during polymerization, at a market price of $15.00/kg. Our input costs include an inoculation of *L. delbrueckii* cells purchased at $294/5 ml, about 11 million kg/year of ammonium hydroxide purchased at $0.30/kg, and 1.9 kg/year of sodium citrate purchased at $0.80/kg. With the raw materials cost at $4.8 million/year, our profit for PLA would be $7.77 million/year before equipment, installation or energy costs.

# 4.0 Customer Requirements

Because both xylitol and PLA are associated with human food consumption, extra care must be taken to assure that no toxic elements remain in the final form of these products. A grave concern for this process is contamination by *Candida* yeast during xylitol production and of the tin oxide catalyst during PLA polymerization. Most other chemicals are common and safe in trace amounts, and are adequately separated out during the respective purification processes.

Zhejiang Huakang Pharmaceutical Inc. is a major Chinese supplier of xylitol from biological sources. They specify at least 98.5% purity of their xylitol products, as well as a host of other maximum contaminant concentrations. Many of the contaminants such as lead, heavy metals, and chlorides are not used in our process, but others such as sulfides and yeasts are. The tests to determine passable concentrations, and the limits on contamination are detailed in Appendix A5. Our intent is to become a supplier to other organizations that will then use xylitol to make gum, dental hygiene products, etc. China is the leading producer of xylitol, so the low cost of shipping from Philadelphia model may help our sales. We expect to sell crystallized, granular food-grade xylitol in bulk quantities.

Polylactic acid (PLA) specifications require a purity of at least 98%. Since this product is approved for food contact, there can be no contamination with toxic substances. PLA is often sold in dry transparent or translucent beads ranging from 2 to 5 millimeters in diameter. NatureWorks LLC is a major worldwide PLA producer, and their technical and safety data sheets can be found in Appendix A2. In order to be able to participate in the market, we must match their specifications. The North American market is currently the largest, which means our Philadelphia-based model can expect steady demand. However, East Asia is currently experiencing rapid growth in demand for PLA, which may justify exploring that region as a potential market.

# 5.0 Principal Chemistry

The relevant chemical reactions in this process include the acid hydrolysis (5.1), pH neutralizations (5.2), enzymatic hydrolysis of cellulase (5.3), fermentation reactions (5.4), and L-lactic acid polymerization (5.5). These reactions are outlined briefly below.

### 5.1 Acid Hydrolysis of Hemicellulosic Mass with Sulfuric Acid

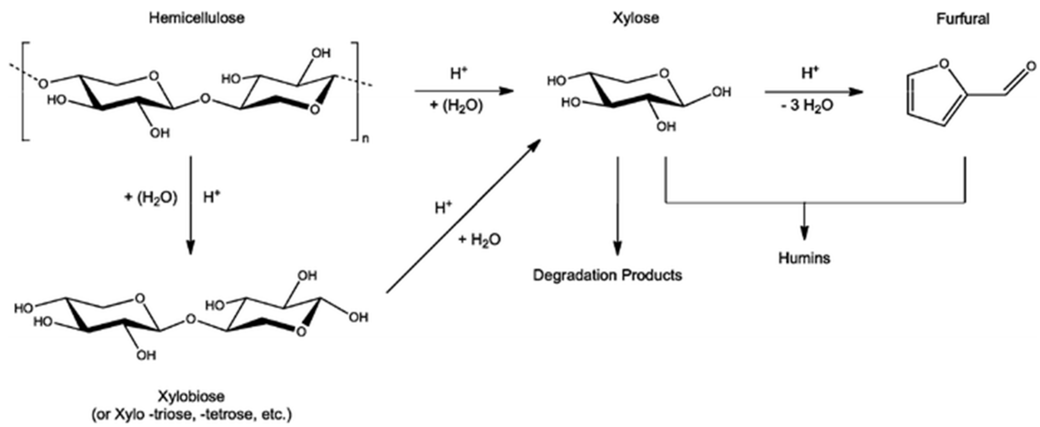



*Figure 5.1 – In the presence of acid, hemicellulose is hydrolyzed into its constituent monomers. Further acidic degradation leads to furfural and other unwanted byproducts.*

Our lignocellulosic biomass (BSG) is treated with a sulfuric acid ($H_2SO_4$) wash at 150°C. The combination of heat and acid depolymerizes the hemicellulose while negligibly affecting the cellulosic matrix. This depolymerization releases pentoses such as arabinose and xylose into solution, as well as forming some lignin degradation products (LDPs) from the hydrolysis of lignin. These LDPs (furfural, hydroxymethylfurfural) are toxic to the downstream fermentation. However, these LDPs are in very small concentration. They are scarce enough not to affect downstream fermentations and will be removed in the xylitol purification process [38].

## 5.2 pH Neutralizations

*Sulfuric Acid Neutralization with $Ca(OH)_2$ (pH 1.5 -> 2.5)*

$$H_2SO_4 + Ca(OH)_2 \rightarrow 2H_2O + CaSO_4$$

In order to bring the pH of the filtrate from 1.5 to 2.5, 13,669kg per day of $Ca(OH)_2$ is added. The pH only needs to be 2.5 because of the unique acidophilic fermentation of *Candida tropicalis*. The reaction generates $CaSO_4$ $2H_2O$, otherwise known as gypsum. This precipitates out of solution, making it easy to centrifuge out before it is fed to the fermenter.

*Xylitol Process Wastewater Neutralization with $Ca(OH)_2$ (pH 2.5 -> 6)*

(Same governing equation as above)

In order for wastewater treatment plants to accept our water output, the stream must be at a pH between 6 and 9. In this step during xylitol purification, 7,389 kg of 2.00 molar calcium hydroxide will be added to achieve this pH. This will form gypsum, which can be centrifuged out of the stream and collected for sale or easy disposal.

## 5.3 Enzymatic Hydrolysis Steps

*Aqueous Ammonia Soaking Treatment of Filter Cake*

The solid product from the drum filter is dropped into a reactor to be soaked with aqueous ammonia. The ammonia selectively breaks down any remaining lignin and hemicellulose, and undergoes saponification and solvation reactions with the cellulosic biomass. The result of this is that the biomass swells, allowing enzymes to more easily penetrate the matrix, and aiding in hydrolysis [15].

*Enzymatic Hydrolysis of Cellulose with Cellulase*

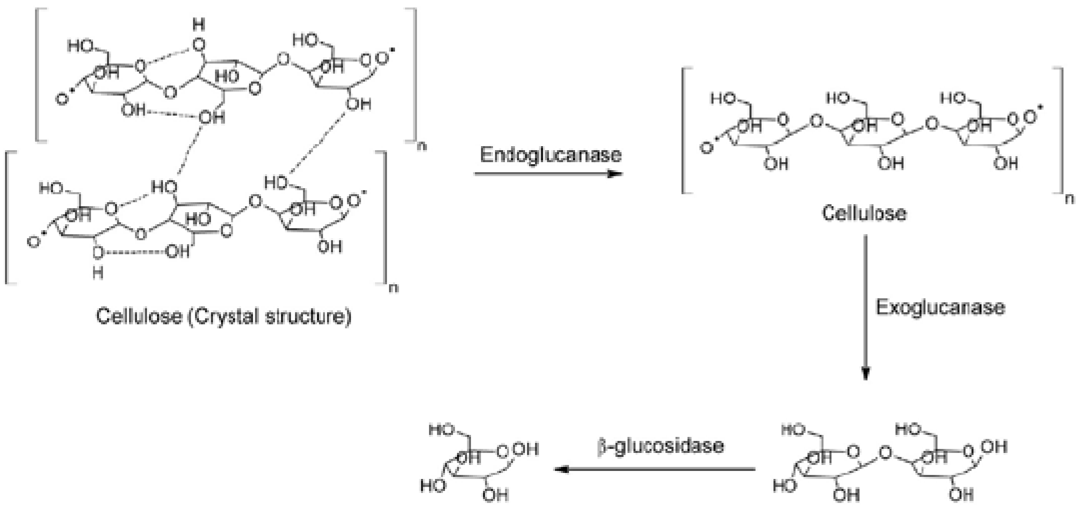



*Figure 5.2 – Figure 5.2 – A series of enzymes (a cellulose cocktail) systematically break cellulose down into simple glucose*

After a wash step to remove the ammonia, the now permeabilized cellulosic biomass is fed into a reactor with cellulase in sodium citrate buffer. The cellulase enzymes hydrolyze the cellulosic matrix into glucose, which goes into solution.

### 5.4 Fermentation Reactions

*Fermentation of Xylose into Xylitol by Candida tropicalis*

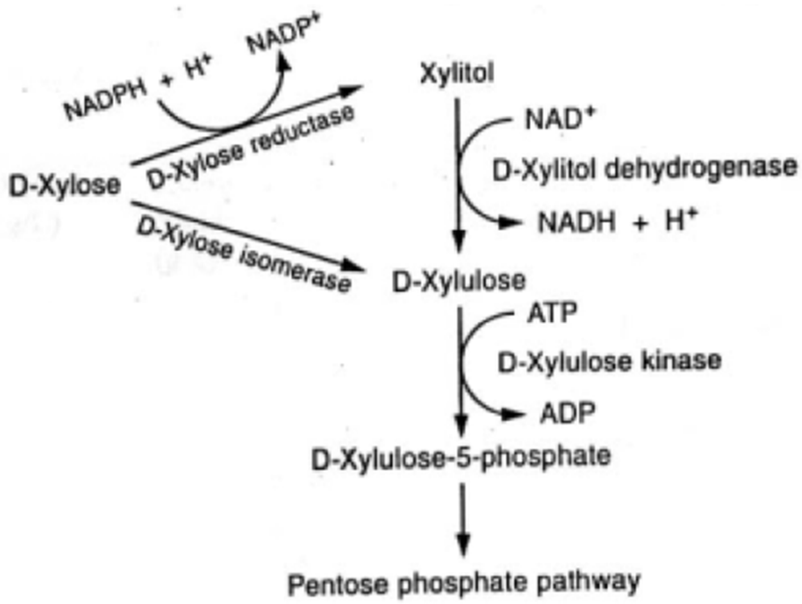



*Figure 5.3 – Figure 5.3 – Preliminary enzymatic pathway before the pentose phosphate pathway. This process makes use of D-Xylose reductase, shown here, which oxidizes NADP$^+$ in order to reduce xylose to xylitol. The subsequent steps do not occur because the necessary enzymes are either not present or are present in very trace amounts.*

*Candida tropicalis* anaerobically ferments D-xylose into xylitol by reducing it using the D-Xylose reductase enzyme. *Candida tropicalis* produces so little Xylitol dehydrogenase and isomerase, that only a negligible amount of xylitol is converted to D-Xylulose and no xylose is converted directly to xylulose. There are some GMOs in which these enzymes are no longer coded for, completely eliminating any xylitol loss to these products. After the reduction, xylitol then diffuses into the extracellular matrix (into solution) [22].

*Fermentation of glucose into L-lactic acid by Lactobacillus delbrueckii*

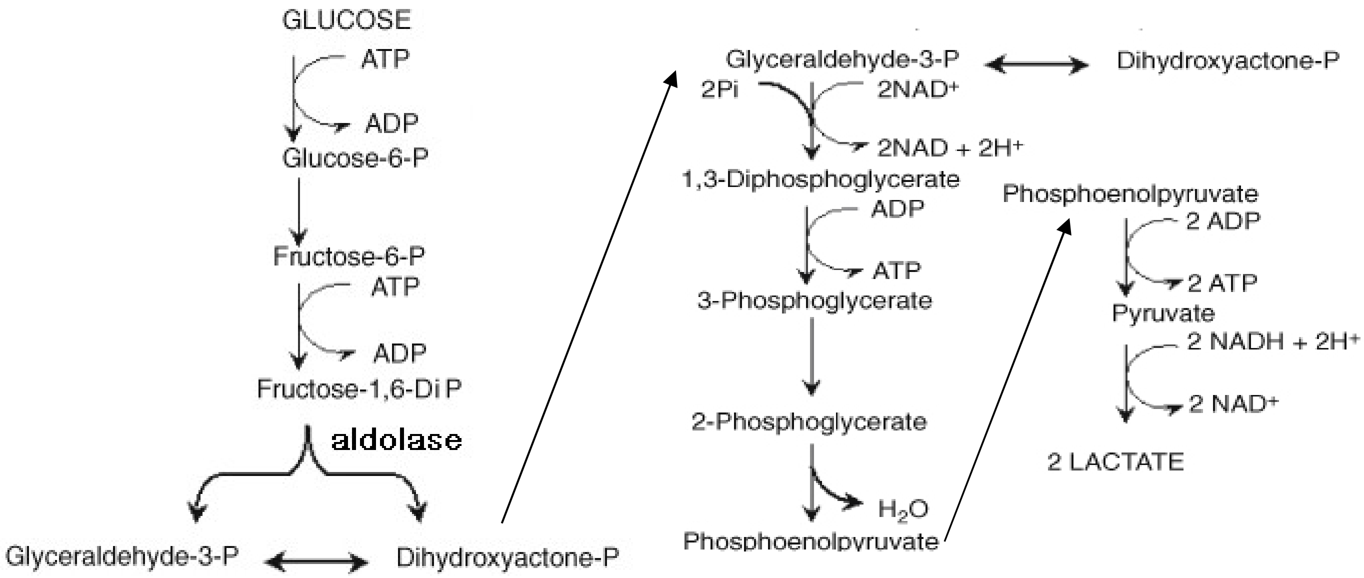



*Figure 5.4 – Metabolic pathway for conversion of glucose into L-lactic acid by bacteria*

*Lactobacillus delbrueckii* is a lactic acid bacteria (LAB) capable of anaerobically fermenting glucose into L-lactic acid according to the above metabolic pathway. The biological process produces a non-racemic mixture of lactic acid isomers, which is very beneficial to the ensuing purification and polymerization. Acidification of the fermentation broth and increasing osmotic pressure - both caused by buildup of extracellular lactic acid - can greatly slow the rate of production. [16] However, because of the continuous nature of this process's fermentation, these concerns are not as pressing, because the flowthrough carries away the lactic acid as it is produced.

**5.5 Polymerization of L-lactic acid into polylactic acid (PLA)**

$$N(C_3H_6O_3) + \quad eat + tin\ oxide\ catalyst \rightarrow N(H_2O) + [C_3H_4O_2 \quad ]_N$$

Pure L-lactic acid in an organic solvent is fed to a reactor that heats the solution to 170°C and contains a tin oxide catalyst. The catalyst allows the lactic acid to polymerize, releasing one water molecule. The high heat also serves to boil off this generated water. Gaseous nitrogen is bubbled through the reactor to assure that no components oxidize. As the polymer passes through the reactor, it can be recycled back in order to undergo more reactions and become larger. In this way, the size of the product can be carefully controlled.

# 6.0 Preliminary Process Synthesis

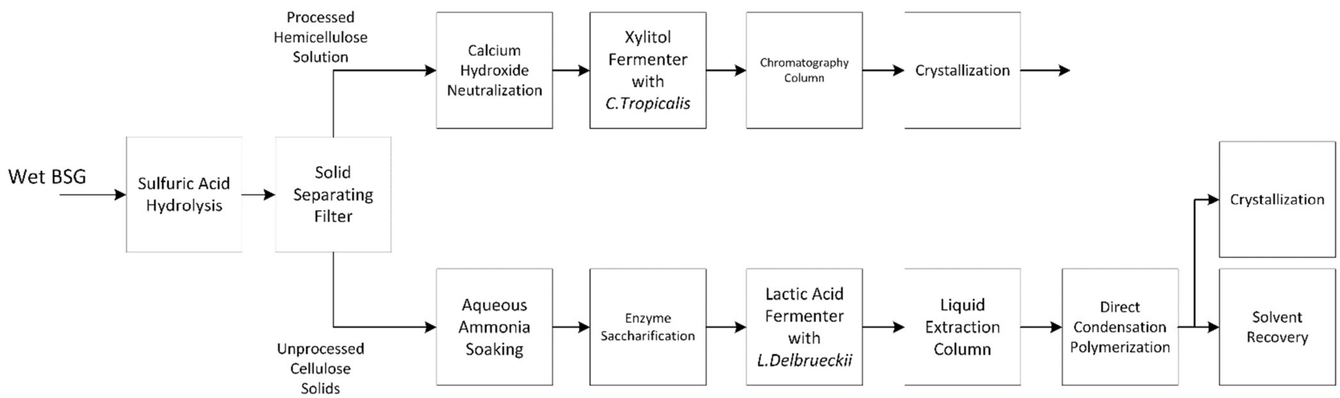



*Figure 6.0 – Process Block Diagram*

## 6.1 Initial Production Designs

The processes for production of ethanol, PLA, and xylitol from brewer's spent grain were each determined and analyzed for their economic viability. The following processes were created through scaling of lab-scale processes found in scientific literature and evaluation of patent literature from large chemicals companies.

The bioethanol process is the simplest of the three spent grain (BSG) fermentation processes evaluated (Figure 6.1).

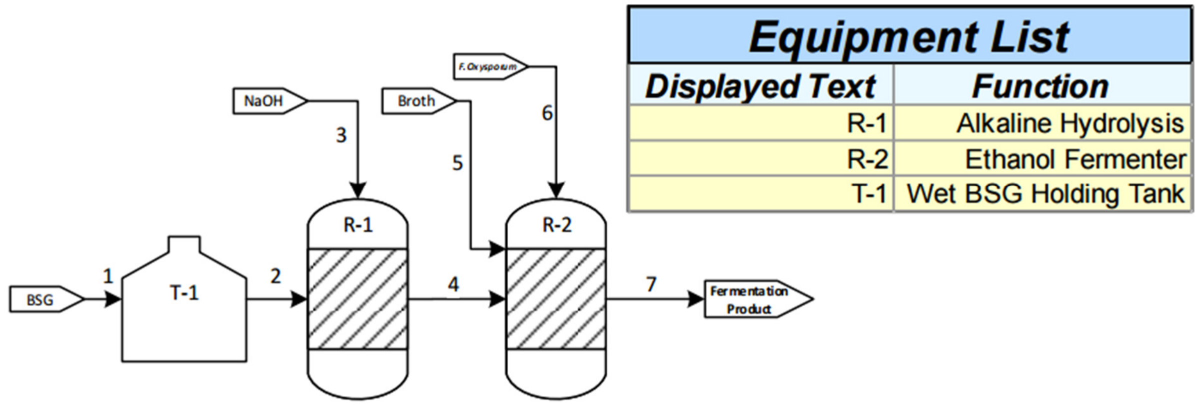



*Figure 6.1 – Bioethanol Process*

In the ethanol process, the wet BSG is first stored in a holding tank (T-1) in order to smoothen out discrete delivery inputs into a continuous process. The wet BSG is then mixed with dilute NaOH in an alkaline hydrolysis reactor (R-1). This reaction breaks down the hemicellulosic material in the BSG into fermentable sugars. Finally, a fermentation is carried out on the hydrolyzed BSG using *F. Oxysporum* (R-2). The resulting ethanol can then be separated using distillation [39].

The xylitol production process requires more extensive pretreatment steps in order to break down the BSG into fermentable sugars (Figure 6.2).

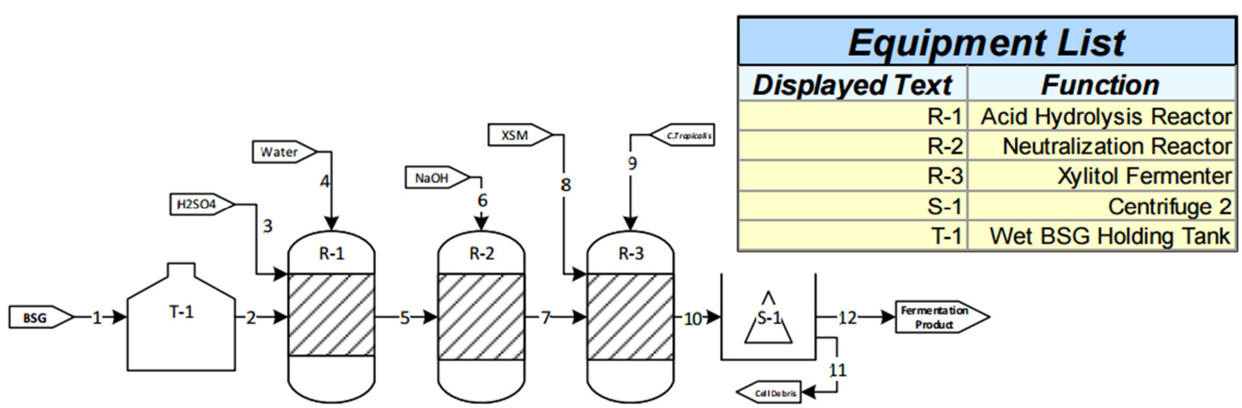



*Figure 6.2 – Xylitol Pretreatment*

Once again, the wet BSG is first stored in a holding tank to allow for continuous operation (T-1). The BSG is fed to an acid hydrolysis reactor along with aqueous sulfuric acid (R-1). Sterile water is added to this reactor in order to dilute the mixture to an 8:1 liquid to solid ratio (Stream 4). In this step, the hemicellulose in the BSG is hydrolyzed to arabinose, glucose, and xylose sugars. Next, the hydrolyzed BSG mixture is combined with NaOH in order to neutralize the stream to the optimal pH required by the fermentation organism (R-2). The stream then moves to the fermenter (R-3). Either *C. guillermondii* or *C. tropicalis* can be used to ferment the sugars in the treated BSG to xylitol in XSM broth. The fermentation product is then centrifuged to remove the cell debris and other solids (S-1). The supernatant from this centrifuge contains dissolved xylitol product [38].

The polylactic acid production process requires the most complex pretreatment steps in order to carry out a successful fermentation (Figure 6.3).

| Equipment List | |
|---|---|
| **Displayed Text** | **Function** |
| E-1 | AAS Wash |
| R-1 | Alkaline Hydrolysis |
| R-2 | Ethanol Fermenter |
| R-3 | Lactic Acid Fermenter |
| S-1 | Centrifuge 3 |
| T-1 | Wet BSG Holding Tank |

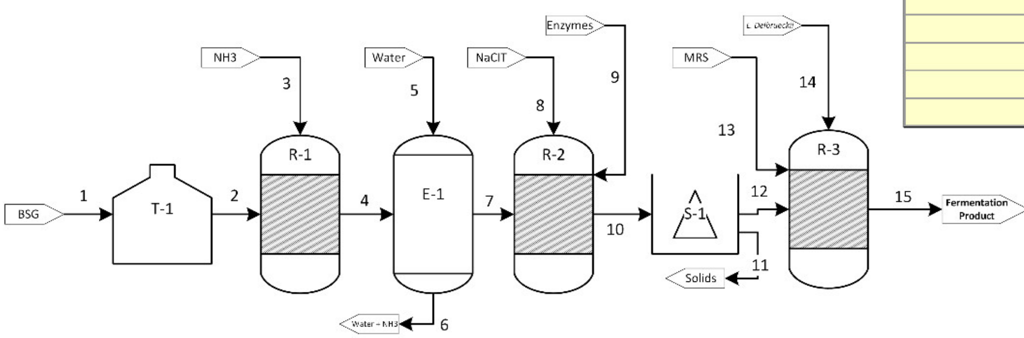



*Figure 6.3 – Lactic Acid Pretreatment*

Following the wet BSG storage tank (T-1), the BSG is fed into a reactor with an aqueous ammonia solution (R-1). The mixture soaks in the ammonia solution, allowing the cellulose solids in the BSG to be more easily broken apart later in the process. In order to neutralize the mixture, it is washed with water until the ammonia is removed (E-1). The treated BSG is then mixed with sodium citrate and cellulase enzymes in a reactor (R-2). The cellulase and sodium citrate break down the cellulose in the treated BSG to yield fermentable glucose. The yields of this reaction are increased by the aqueous ammonia soaking pretreatment. Next, the mixture is centrifuged to remove all solids (S-1) and the supernatant fed into the fermenter (R-3). Either *L. delbrueckii* or *L. acidophilus* can be used to ferment the glucose in Man, Rogosa, Sharpe (MRS) broth. Unlike the ethanol and xylitol processes, the fermentation bioreactor in the polylactic acid process does not produce the final product. Instead, the fermentation produces L-lactic acid which must then undergo additional processing to be polymerized into polylactic acid [37].

### 6.2 Batch vs. Continuous Fermentation

An important early decision when considering fermentation processes was whether to pursue batch or continuous fermentation designs. In a batch fermentation process (Figure 6.4), the incoming continuous stream of fermentable sugars must first be converted into discrete inputs for a batch fermenter. This is accomplished by feeding the stream into a large storage vessel (E-1) and allowing it to accumulate continuously while each batch fermentation is taking place. Since one batch fermentation can take multiple days to complete, multiple fermentation reactors must be built (R-1) and scheduled in such a way so that the system can process all of the fermentable sugars generated by the continuous process in one batch time. The more fermenters are used, the smaller they can be, and the smaller the holding tank can be, because it can discharge into a new reactor more often. This necessitates balancing the cost of many small reactors against a few large ones. Economies of scale usually lean more toward fewer larger vessels. However, acceptable risk must also be considered. If one of six smaller batches become contaminated, it makes a much smaller impact than if one of two larger batches are.

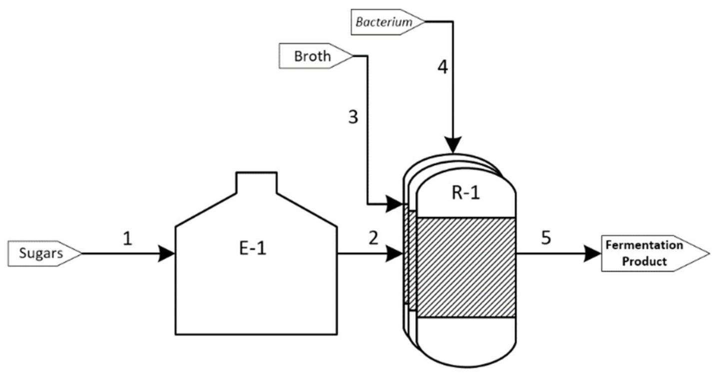



*Figure 6.4 – Batch Fermentation Process*

A continuous fermentation process requires fewer pieces of equipment than a batch process (Figure 6.5). No holding tank is required between the sugar solution stream and the fermenter, and only one fermenter is required (R-1), thus saving space and cost of equipment. Additionally, by setting the dilution rate equal to the specific growth rate, the organism that is growing in the fermenter can maintain at its peak growth rate at all times. In this case, where the desired products are primary metabolites, this stage of the growth curve leads to the most efficient conversion of sugars to product.

A major downside to continuous processing is the risk of contamination. A contaminated continuous process can ruin large amounts of product, and puts a halt to the entire process while the stock is drained and the apparatus is sterilized. If a batch fermenter gets contaminated, only that batch is affected, and will be cleaned and sterilized anyway.

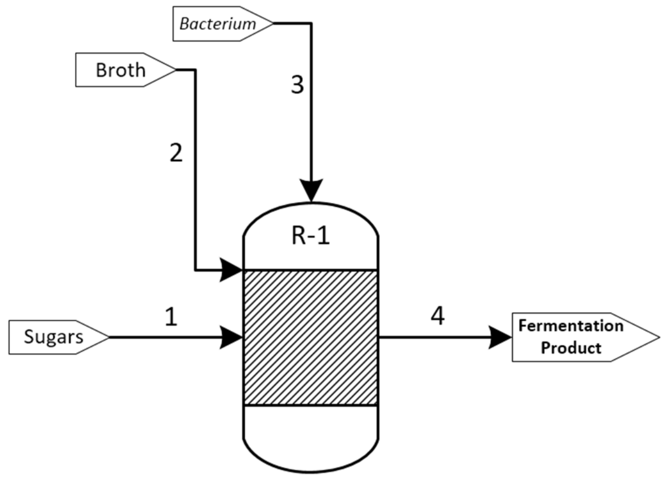



*Figure 6.5 – Continuous Fermentation Process*

In both batch and continuous processing, a Clean in Place (CIP) unit will be required for regular cleaning of units which come into contact with organisms, and which operate under high temperatures or pressures. Such units include the fermenters and the acid hydrolysis reactor. For this reason, and to provide a contingency in case of contamination, duplicate fermenters should be installed regardless of whether the operation mode is batch or continuous.

### 6.3 Purification of Products

Due to the economic analysis of the ethanol fermentation process presented in Section 7, ethanol was not chosen as a product and therefore its purification process was not considered. Instead, processes for the purification of xylitol and polymerization of lactic acid were explored and evaluated.

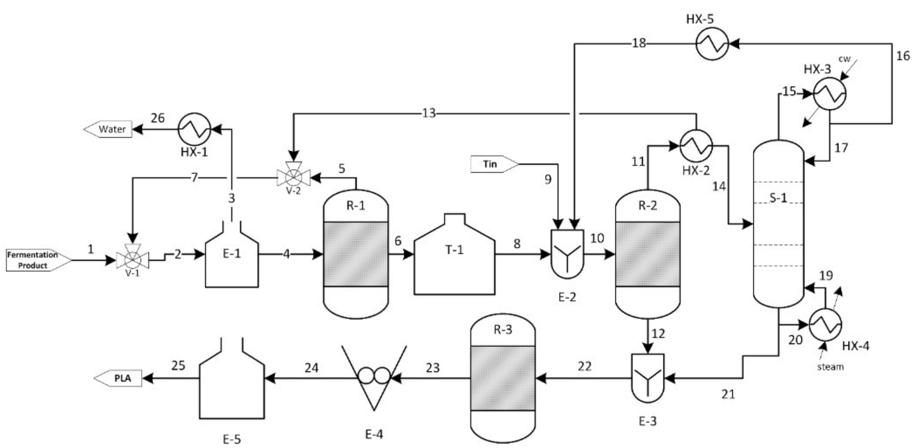
The fermentation product from breaking down xylose is aqueous xylitol, which contains some impurities. Purification is difficult due to the complex components and low product concentration in the broth [13]. The impurities include cells, fermentation broth, arabinose, glucose, and other salts. The processes considered for the purification of xylitol from the aqueous fermentation product were using a standard ion exchange chromatography treatment or using and activated charcoal treatment. The chromatography treatment, outlined in US Patent 3985815 A and 4008285 A, requires two ion exchange chromatography columns; one cation ion exchange resin, and one anion ion exchange resin. The exchange resins are able to purify the solution by exchanging particular ions within the polymer of the resin. When using a recycle stream during the crystallization process, the overall yield of crystal xylitol from the aqueous product can be has high as 95%. The purity is confirmed to be 99.9%. The first patent was filed for this process in 1976, and many industrial scale processes still use the design.

The activated charcoal treatment is a recently founded process, with the first literature dating back to April of 2006 [13]. It uses adsorption through activated charcoal and vacuum concentration, along with a precipitation with ethanol. The precipitate then goes through similar evaporation and crystallization processes as the chromatography method. It requires about 4 cycles of crystallization to obtain yields of 76.20% from the fermentation broth. The crystalline product has about 98.99% purity [14].

Both processes obtain crystalline form of xylitol from the purified broth using evaporation at 50°C and crystallization at 5°C. The final product must be steam sterilized, regardless of purification process, to remove any possibility of the toxic *Candida* strain. While other methods exist, like liquid-liquid extraction, these two choices were explored as they resulted in the highest yields of crystalline xylitol.

Lactic acid has two enantiomers, L and D lactic acid, that differ in the ease at which they can be converted to polymer form. Fortunately, the L-lactic acid produced by fermentation is the easier of the two stereoisomers to polymerize, allowing for fewer processing steps. Polylactic acid can be created from L-lactic acid through two possible reactions: direct condensation polymerization or lactide ring opening.

A process for the synthesis of polylactic acid from L-lactic acid through lactide ring opening was patented by Cargill in 1992 (Figure 6.6). This process is unique because it does not require the acid to be transferred to an organic solvent. Instead, the lactic acid is entered into the process as an aqueous solution, saving on the cost of extraction from the fermentation product.




| Equipment List | |
|---|---|
| **Displayed Text** | **Function** |
| E-1 | Evaporator |
| E-2 | Mixer |
| E-3 | Mixer |
| E-4 | Pelletizer |
| E-5 | Drier |
| HX-1 | Condenser |
| HX-2 | Partial Condenser |
| HX-3 | Total Condenser |
| HX-4 | Partial Reboiler |
| HX-5 | Total Condenser |
| R-1 | Pre-Polymerization Evaporator |
| R-2 | Lactide Reactor |
| R-3 | Polymerization Reactor |
| S-1 | Distillation Column |
| T-1 | Holding Tank |

*Figure 6.6 – Cargill PLA Production Process*

The lactic acid stream first moves through an evaporator (E-1) that removes water from the stream to concentrate the solution. A pre-polymerization evaporator (R-1) then removes additional water under conditions that allow the L-lactic acid to begin polymerizing. The solution is then fed to a holding tank (T-1) before it is mixed with a tin catalyst and additional recovered lactic acid solution. This mixture is transferred to a reactor in which the L-lactic acid reacts over the tin catalyst to form lactide rings. Within the reactor, a lactic-acid rich vapor phase and a lactide-rich liquid phase are formed. The liquid is removed from the reactor and entered later into the process.

The vapor is removed and partially condensed (HX-2). The vapor is mixed with the water extracted in R-1 and mixed with the feed stream (V-1). The liquid is fed into a distillation column (S-1) in which the remaining lactide rings are separated from the lactic acid solution. The distillate from the distillation column is condensed (HX-5) and mixed with the lactic acid solution in E-2. The lactide-rich bottoms product of the distillation column is mixed with the lactide mixture produced in R-2 (E-3) and fed to a lactide ring-opening reactor (R-3). In the reactor, the lactide rings open and combine with each other to form high molecular weight polylactic acid. The polylactic acid is removed, fed into a pelletizer (E-5) and then dried (E-5). The resulting product consists of condensed pellets of high molecular weight PLA [36].

A process for producing polylactic acid from L-lactic acid via direct condensation polymerization was patented in the 1980s (Figure 6.7). Condensation polymerization processes require that the L-lactic acid be dissolved in an organic solvent before undergoing the polymerization reaction. Therefore, in order to implement the process following a fermentation, the lactic acid would have to be extracted.

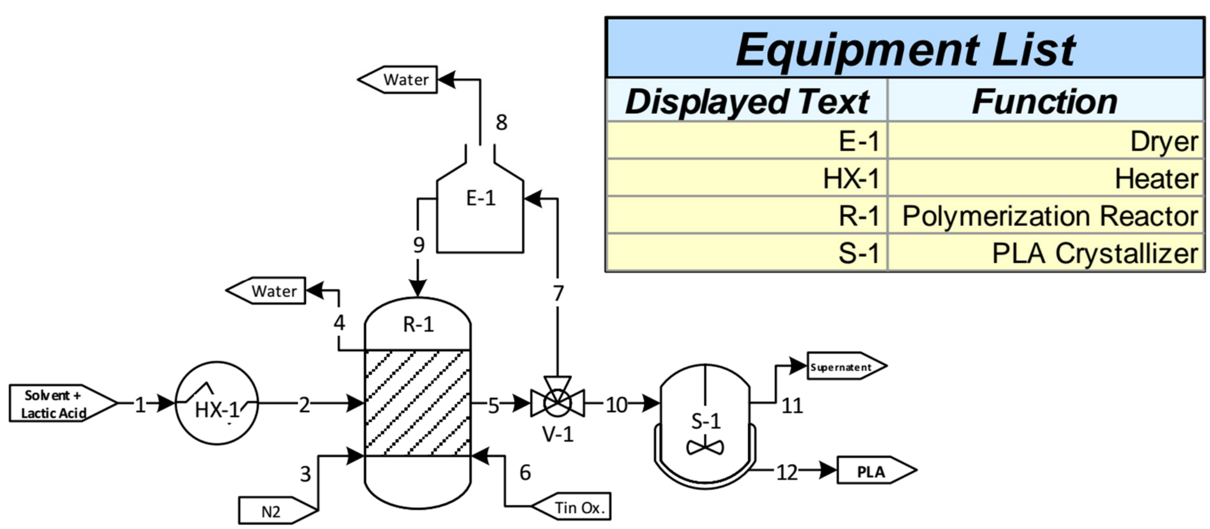
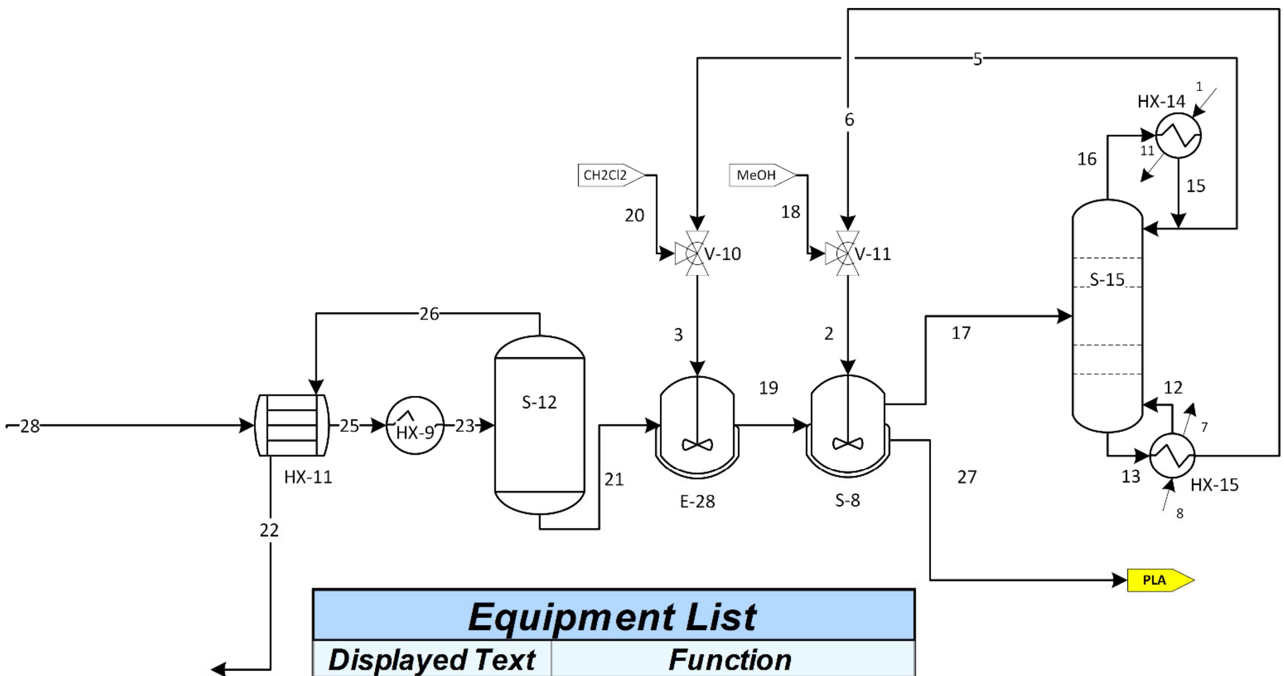



*Figure 6.7 – Direct Condensation Polymerization Process*

After the lactic acid has been dissolved in an organic solvent, it passes through a heat exchanger (HX-1) and is heated to 170 degrees C. The heated stream is then fed into a polymerization reactor (R-1) along with a tin oxide catalyst. Nitrogen gas is bubbled through the reactor in order to maintain an inert atmosphere while the lactic acid polymerizes over the tin oxide catalyst. As the condensation reaction occurs, water is released and boiled off. The water vapor is removed from the top of the reactor. Following the polymerization reaction, the solution of PLA is removed from the reactor and fed to a splitter (V-1). A fraction of the PLA solution is sent to an evaporator that dries the solution (E-1) before recycling it back into the polymerization reactor. This recycle loop allows for the polymerization to continue to reach higher molecular weight PLA. The second stream of PLA solution exiting the splitter is fed to a separation vessel that is used to separate the organic solvent. The PLA is then dissolved in dichloromethane and subsequently mixed with methanol in a crystallizer (S-1). The methanol added to the dichloromethane mixture creates conditions in which the PLA can be crystallized and removed as a purified solid [35].

### 6.4 Recovery of Polylactic Acid Process Materials

Two processes were considered to recover the solvents used in the polylactic acid polymerization process. The first process is intended to recover highly pure streams of each solvent that can be recycled (Figure 6.8).

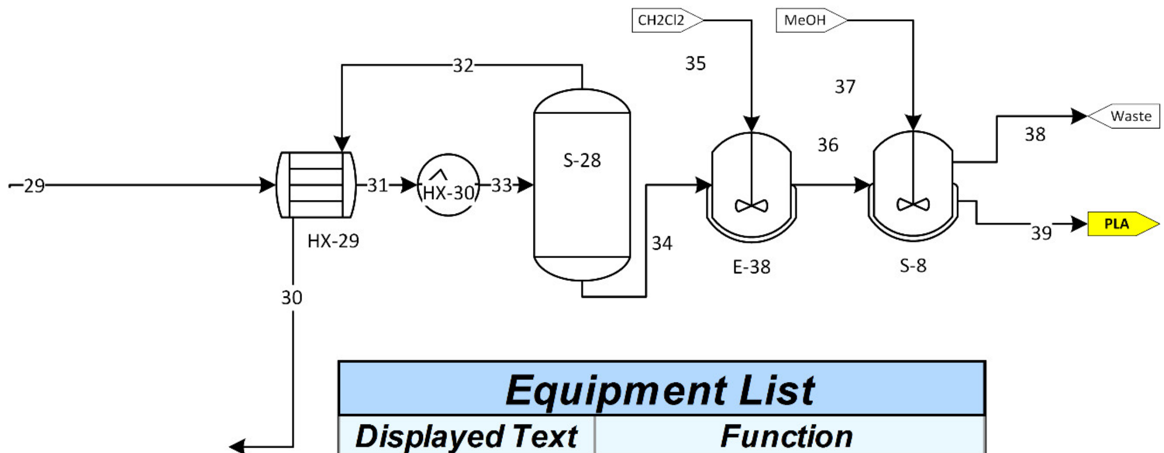



| Equipment List | |
|---|---|
| **Displayed Text** | **Function** |
| E-28 | Dichloromethane Mixer |
| HX-11 | Distillate to Bottoms Exchanger |
| HX-14 | Total Condenser |
| HX-15 | Partial Reboiler |
| HX-9 | Heater |
| S-12 | Ether Separating Flash Drum |
| S-15 | Solvent Distillation Column |
| S-8 | PLA Crystallizer |

*Figure 6.8 – Solvent Recycle Process*

The top stream from the PLA and solvent separator is fed to a flash vessel (S-12) that separates any water and lighter components from the heavy organic solvent. The bottoms is rich in the organic solvent, and is fed back to the polymerization reactor in Figure 6.7 (R-1). To recover the other solvents, the liquor stream from the crystallizer (S-8) containing primarily methanol and dichloromethane is fed to a tray distillation column (S-15). The distillate of the column (5) is rich in dichloromethane and the bottoms (6) is rich in methanol. Each stream is recycled to its respective mixing step in Figure 6.8. This solvent recovery method allows for all of the solvents used to be treated as capital costs rather than operating costs of the process. Dichloromethane and methanol have similar boiling points (39.6°C and 64.7°C respectively) when compared to that of a likely organic solvent (on the order of ~200°C), however their boiling points are far enough apart to make distillation a feasible economic option. The separation performed by the tray distillation column may add additional cost, but does limit the operating costs of purchasing new solvents and is the more promising option overall.

The second solvent recovery process addresses the issue of separation cost by focusing solely on recovering the majority of the organic solvent (Figure 6.9). This process is identical to the process described above, however it removes the tray distillation column used to separate dichloromethane and methanol. Instead, the liquid stream exiting the crystallizer is treated as waste




| Equipment List | |
|---|---|
| **Displayed Text** | **Function** |
| E-28 | Dichloromethane Mixer |
| HX-11 | Distillate to Bottoms Exchanger |
| HX-14 | Total Condenser |
| HX-15 | Partial Reboiler |
| HX-9 | Heater |
| S-12 | Ether Separating Flash Drum |
| S-15 | Solvent Distillation Column |
| S-8 | PLA Crystallizer |

*Figure 6.9 – Alternative Solvent Recovery Process*

and thrown away. In this process, the separation costs are minimized, however the dichloromethane and methanol in the process cannot be treated as capital costs and must be re-purchased every day of operation.

## 6.5 Synthesis Tree

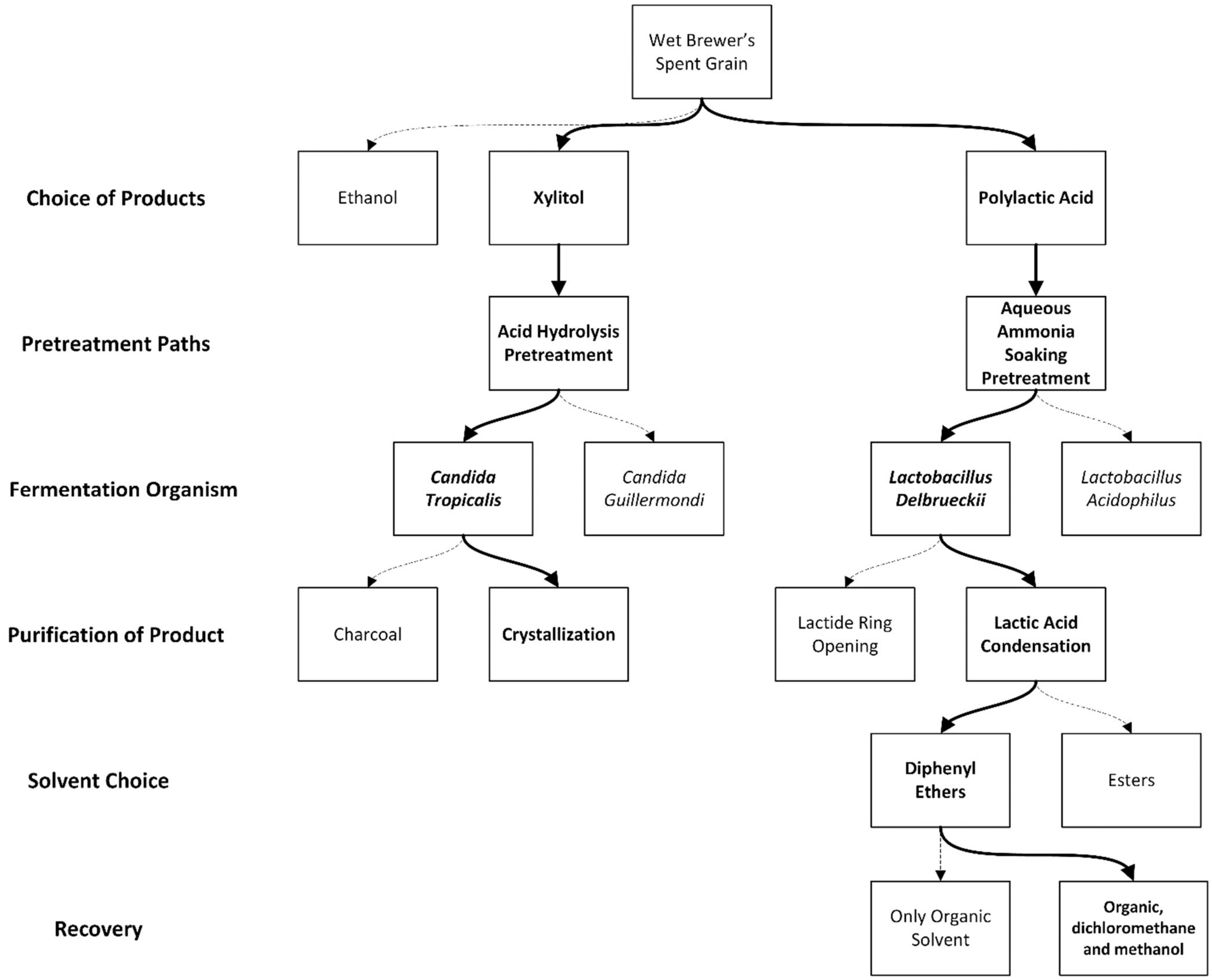



*Figure 6.10 – Synthesis Tree for Selected Process*

# 7.0 Block Diagram and Process Explanation

### 7.1 Block Diagram

The following block diagram shows an overview of the final processing steps chosen along with the major input and output streams and their flow rates (Figure 7.1).

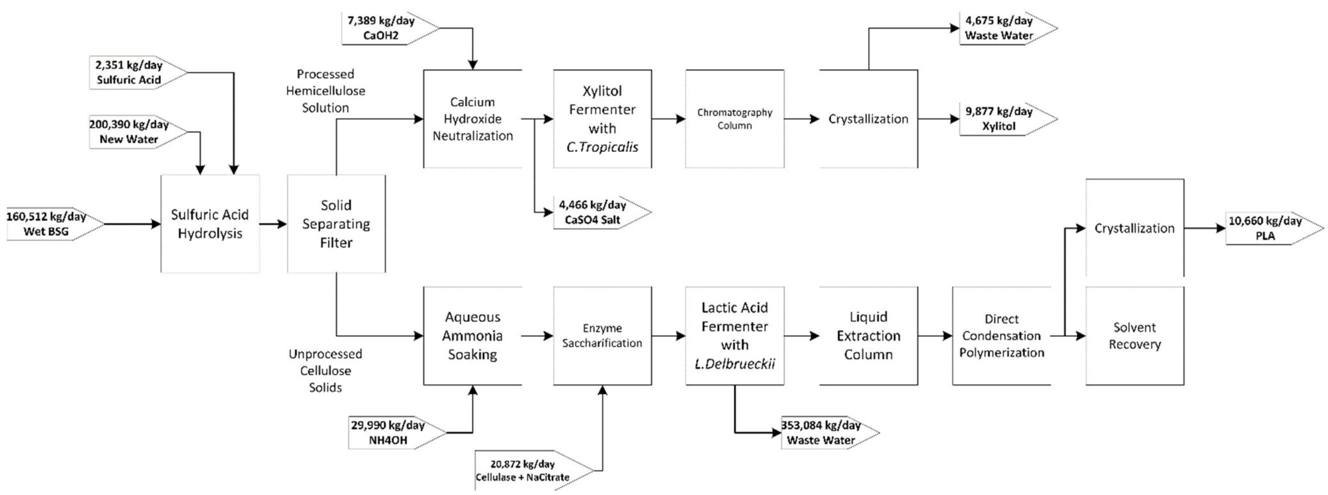



*Figure 7.1 – Block Diagram with Major Stream Flow Rates*

*Pretreatment Processes*

It was decided to pretreat the BSG to be converted into both xylitol and PLA. With the correct pretreatment, the BSG can be separated into its different components without affecting the yield of either product. BSG is a mostly lignocellulosic biomass, meaning that its main structural component is a combination of cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are the well-known polysaccharides made up of 6-carbon and 5-carbon linkages, respectively. Common 5-carbon sugars found in hemicellulose include arabinose and xylose. Hemicellulose is much more easily broken down than cellulose, which lends itself well to separation. Lignin is a connective polymer made up of phenolic monomers, and it plays little role in this process. The only consideration given to lignin is that it will break down into compounds that hinder fermentation if it is degraded too aggressively. Since the two sugars of interest exist in different matrices (hemicellulosic and cellulosic), and each process only uses one of these sugars, one pretreatment can be performed on the whole feed to separate the two.

A dilute sulfuric acid hydrolysis is used to break down the hemicellulose into sugar monomers (xylose and arabinose, some trace others) in solution. This process affects a negligible amount of the cellulose, leaving most of it intact. It also breaks down a small amount of lignin, but not enough to have an appreciable impact on the fermentation. The resulting slurry is then put through a filter. The sugars in solution will pass through the filter to be processed further into xylitol. The solid cellulose matrices will not, and will be collected for further processing and eventual fermentation into lactic acid, and then PLA.

*Xylitol Fermentation*

The first major decision with regard to fermentation is that of whether the process will be in batch or continuous. Batch is more traditional and easy to control, but requires more equipment and a lot of resources spent on initial cell grow-up. A continuous process can save a lot of money and be lead to more efficient production of the product, but it comes with some extra risks - especially that of contamination. This risk played an important part in choosing which organism would be used to ferment xylose into xylitol.

*Candida guillermondii* was the initial choice, as there is a wealth of literature about its ability to perform the needed fermentation. However, upon further research, a strain of *Candida tropicalis* was found that possessed better reaction kinetics and performed best in highly acidic conditions. This strain prefers the fermentation to take place at a pH of 2.5. This is far too acidic for most microorganisms to thrive, so contamination is not a concern for this process. Thus, the biggest risk associated with continuous fermentation is avoided. The low pH also allows much less CaOH to be used to neutralize the input stream, which saves money. There appears to be many strains of *Candida tropicalis* that have been researched for similar processes. Some genetically modified strains possess other highly desirable properties, such as the ability to convert arabinose into xylitol, and the inability to convert arabinose into arabitol (a possible toxin to the fermentation process). This leaves open the possibility of obtaining one of these strains or engineering one with an optimal combination for enhanced production.

After passing through the fermenter, the effluent will be centrifuged to remove all of the yeast, and the flow through from this will be steam treated to make sure that the xylitol broth is completely sterile. This is very important because *Candida* yeasts are toxic to humans. Some of the xylitol stream is also recycled back to the fermenter so that more of the remaining xylose sugars in the stream can be converted to xylitol and increase overall yield.

*Xylitol Purification Process*

There were two main processes researched for aqueous xylitol purification: chromatography and activated charcoal treatment. It was decided that using two ion exchange resins was the most cost effective and simple purification process for many reasons. While the ion exchange resins are a large capital cost, they are extremely cost effective in that no solvent needs to be regularly replaced and the maintenance is rather cheap. For non-water solutions, cation exchange resins have lifespans of 5-10 years, while anion exchange resins typically last 3 to 5 years. It has a small footprint and zero effluent and waste generated. The capital cost is large because backup ion exchange resins will be required due to the regeneration needs of the columns.

The charcoal treatment, on the other hand, has a lower capital cost but is difficult to scale up to an industrial continuous process. It has a much larger footprint and multiple effluent streams. Exhausted charcoal and an ethanol precipitate would need to be disposed of safely and properly. The activated charcoal and input ethanol would add to fixed costs for our process.

The largest relevant distinction between the two methods is the crystalline product yield. The chromatography method has a 95% recovery of crystalline xylitol from the fermentation broth with recycle, while the charcoal treatment only has 76.20% with four cycles of crystallization [2]. While more recent literature shows great promise for increasing the yield using activated charcoal, the current yield and purity is not suitable for this project.

*Lactic Acid Fermentation*

Lactic acid fermentation is a relatively common process, often involving bacteria of the genus *Lactobacillus*. This process will use *Lactobacillus delbrueckii* to convert glucose into L-lactic acid. *L. delbrueckii* was chosen over the more common *acidophilus* because of the discovery of a method of significantly increasing the yield. As lactic acid is produced, the pH of the culture drops until at some point it begins to adversely affect the rate of reaction. If the pH is kept at a neutral or near neutral level (~6.0), the bacteria will continue to operate at maximum capacity, leading to a 98% conversion of glucose to lactic acid. This is a significant increase over its unregulated yield of 86%.

This fermentation will also be carried out continuously, as the glucose conversion occurs during the cell growth phase. The effluent will be filtered through liquid extraction to remove everything except the L-lactic acid.

*PLA Synthesis*

It was chosen to synthesize polylactic acid via a direct condensation polymerization reaction of L-lactic acid rather than lactide ring opening. This decision was made based on two primary criteria: heating energy costs and fermenter stream separation costs. Despite the lactide ring opening process' use of water as its solvent, the effluent stream from the lactic acid fermenter is not a pure solution of water and lactic acid and would have required processing before being entered into the lactide ring opening process. First, the various salts and fermentation by-products in the stream would have to be separated via crystallization, distillation, or other means. In addition, a purified solution of water and lactic acid would need to be distilled to a lactic acid concentration of 15 wt. % for the polymerization process to be effective. The fermenter exit stream is predicted to have a lactic acid concentration of 12.7%; therefore, 46,800 kg of water would have to be distilled off per day. This purification and concentration of the fermenter effluent would introduce additional energy and equipment costs. As the lactide ring opening process already requires numerous evaporators, condensers, reactors and a tray distillation column, it was felt that the additional costs associated with fermenter stream pre-processing would simply push the cost too high.

In contrast, the process of direct condensation polymerization of lactic acid is much simpler, only requiring one central reactor, one evaporator, one crystallizer and one flash vessel to produce a PLA product. The fewer pieces of equipment needed by this process allowed for more complex solvent recovery processes to be implemented and also were thought to reduce the overall costs of the process. The molecular weight of the PLA product is also able to be more finely controlled in the direct condensation process and scales with the amount of polymerization reactor effluent recycled back to the reactor. This control would allow a PLA production facility to adapt the final PLA product to different markets based on the molecular weight of the PLA. In the event of a decline in low molecular weight PLA prices, a plant using this direct condensation process could choose to produce a higher molecular weight PLA and vice versa. It was felt that this flexibility would contribute to a more stable business.

Despite the fact that the direct condensation process requires the use of multiple solvents rather than keeping the lactic acid in an aqueous solution, it actually proved to be the superior option. Initially transferring the lactic acid from the fermentation broth to an organic solvent cuts down on both the equipment and energy costs of purifying and concentrating the broth for the lactide ring opening process. The organic solvent chosen for the direct condensation process was diphenyl ether. Diphenyl ether was chosen due to its immiscibility in water, ability to preserve high molecular weight polylactic acids in solution, and high boiling point of 258°C. Rather than first heating the fermentation broth and feeding it to flash vessels to purify and concentrate it, a liquid extraction into diphenyl ether can be carried out on the broth at room temperature without any purification or concentration steps. Additionally, with some separation steps the diphenyl ether can be recycled and treated as a capital cost rather than an operating cost.

However, the dichloromethane and methanol required for the direct condensation polymerization process pose significant costs. Priced at \$0.405 and \$0.500 per kilogram respectively, replenishing the dichloromethane and methanol required for the PLA process would cost approximately \$51,000 per day in material costs. Therefore, it was decided to separate the solvent mixture using a tray distillation column in order to recycle each component. Following the PLA crystallization, the exit methanol and dichloromethane solution is distilled and each component recycled. This process recycles virtually all of the solvent, essentially eliminating the operating costs of adding new solvent and disposing of waste solvent.

# 7.2 Aspen Modelling Assumptions

A number of assumptions were made in order to simulate the process in Aspen Plus V9 simulation software. The following section details the general thought process that went into making the assumptions -- for a full printout of the final Aspen Plus V9 input file, see Appendix A3.

*Component Assumptions*

No solids processing simulations were performed in Aspen Plus. Instead, components that exist as solids in the process were given the property sets of inert or innocuous compounds. For example, cellulose solids were modelled as fructose and other solids were modelled as heavy water (deuterium oxide). To ensure that these 'solids' moved through the process in expected ways, separator blocks were used in place of rigorous filter or centrifuge blocks to send the 'solids' one direction and the liquids in another. In equipment sizing, however, these separator blocks were evaluated correctly.

To simplify the model, a number of component groupings were made. Non-cellulosic solids and nonfermentable solutes were grouped together into "Other Solids" and "Other Liquids," respectively. Similarly, all fermentable sugars produced were treated as "xylose" in the acid hydrolysis step and "glucose" in the saccharification reaction step and cellulose and hemicellulose were both treated as "cellulose." This Aspen 'cellulose' was affected by both the xylitol and the lactic acid pretreatments despite them being separately affected in reality. To compensate for this in hydrolysis reactions, the stoichiometry of each reaction was adjusted so that the mass of real hemicellulose or cellulose consumed was reflected in the change in mass of Aspen's 'cellulose'. For example, say that the feed stream to the sulfuric acid hydrolysis consists of 5 grams of cellulose and 5 grams of hemicellulose. In reality, the hydrolysis would consume ~5 grams of hemicellulose and produce ~2 grams of arabinose, ~2 grams of xylose and ~1 gram of glucose leaving the cellulose untouched. In the Aspen simulation, this reaction is modelled as 10 grams of 'cellulose' being converted into 5 grams of 'cellulose' and 5 grams of 'glucose'. This simplification is further demonstrated in figure 7.2.

**Reality**

$$5\ Hemicellulose + 5\ Cellulose \rightarrow 2\ Xylose + 2\ Arabinose + 1\ Glucose + 5\ Cellulose$$

**Simplifying Assumptions for Model**

$$10\ Processable\ Solids \rightarrow 5\ Fermentable\ Sugars + 5\ Processable\ Solids$$

**What Aspen Models**

$$10\ \text{"Cellulose"} \rightarrow 5\ \text{"Glucose"} + 5\ \text{"Cellulose"}$$

*Figure 7.2 – Example of Component Assumptions*

Lastly, since neither xylose nor cellulase enzymes are ever present in the same stream, both compounds were modelled as 'xylose'. These groupings trim down the number of by-products that Aspen simulates and allows results to be understood easier.

The Aspen Suove-Redlich-Kwong equation of state was selected to describe the thermodynamic interactions in the simulation. This equation of state was selected due to its ability to estimate equilibrium data for all of the components in the simulation both individually and in mixtures. Thermodynamic properties of each compound were, for the most part, present in the Aspen default databases. However, the properties of ammonium hydroxide and calcium sulfate were not fully present. The boiling point, critical temperature, critical pressure, and acentric factor for each of these compounds were researched and entered manually. Polylactic acid was not a compound present in the default Aspen databanks. An attempt was made to work with Dr. Len Fabiano and Aspen support specialists to create an accurate polymer model, however this approach proved inefficient and overly complicated. Due to the PLA's high molecular weight, viscosity and boiling point, it is unlikely that the presence of PLA in a solution would alter its thermodynamic properties significantly. Therefore, it was decided to use the Aspen information for n-dodecane to model most of the thermodynamic properties of PLA. In order to ensure that the PLA remained a liquid in any flash calculations, the boiling point, critical temperature, and critical pressure were manually set at 2000 C, 3000 C, and 5 atm respectively. The molecular formula of PLA was set to be C3300H4400O2200 in Aspen's property editor -- Aspen therefore calculated a molecular weight of 79,270 for the PLA model. This approximated model of PLA ensured that the polymerization reaction stoichiometry and flash block calculations were accurate.

*Reaction Modelling Assumptions*

Most of the chemical reactions in the process -- including the xylitol and lactic acid fermentations -- were modelled using the RYield block in Aspen. The only two reactions that were not modelled this way were the CaOH2 neutralization reaction and the lactic acid direct condensation reaction. These reactions were both modelled as RStoic. The RYield method was chosen for most of the reaction models because it allowed for the component simplifications described in the preceding section to be applied accurately. The RStoic model could not have been used in these cases due to the inconsistency of the molecular formulae of each component. The simplifying assumptions made in component selection meant that a stoichiometric balancing of the chemical equations was not possible in reactions that contained approximated components. RYield allowed for these reactions to be simulated despite the fact that the atomic balance around the reactor did not close. However, the RStoic model was able to be applied to the CaOH2 neutralization and the lactic acid polymerization reactions because the components involved were modelled with the correct molecular formulae. Both of these reactions were assumed to complete fully with a yield of 100%. The polymerization reactor contained some further simplifications. Additionally, the nitrogen gas bubbled through the reactor and the solid tin oxide catalyst over which the reaction is performed were not modelled in Aspen. This was done because the presence of nitrogen or tin oxide in the reactor model did not impact the simulation results and neither the nitrogen nor catalyst could be modelled as remaining within the reactor. This meant that in the simulation the nitrogen and tin oxide would be carried out in the reactor effluent and influence thermodynamic calculations further along in the process. Removing these components could have been accomplished by adding a separator block to the process, however this block would then be automatically evaluated by the Aspen integrated economics module as a capital cost of the process, requiring more tinkering with the simulation to remove its costs. The best solution was simply to remove the nitrogen gas and tin oxide catalyst from the process model.

*Design Specifications and Stream Flow Estimates*

The water and diphenyl ether recycle streams in the process were modelled using design specifications. Each recycle stream in the process was mixed with an external input stream of the same compound. A design specification was then implemented that varied the flow rate of the external input stream until the combined mixer output stream contained the desired amount of the recycled compound. The design specs all varied the input flow rate beginning at zero and ending when the loop converged. The flow rate of the diphenyl ether stream that would produce the optimal liquid extraction was estimated using a sensitivity analysis that recorded various separation mass fractions as they varied with diphenyl ether flow rate.

The desired methanol and dichloromethane input flow rates were estimated from experimental data found in polylactic acid crystallization literature. A design specification was implemented that set the input flow rate of dichloromethane into the PLA stream at 600 L per kg of PLA. A second design specification set the input flow rate of methanol at 4 L methanol / 3 L dichloromethane.

Another design specification was implemented that varied the temperature of the diphenyl ether recovery flash vessel (S-13) in order to maintain the diphenyl ether recovery stream at 99 weight % diphenyl ether.

*Equipment Sizing and Stream Costing Assumptions*

Equipment sizing, bare module costing, and utilities pricing were completed using the Aspen Process Economic Analyzer (APEA). All of the equipment materials were modelled in the APEA as stainless steel SS304. This was done in order to make the equipment cost estimate generated by the APEA a high-end estimate, since it is likely that not all of the process equipment would be stainless steel in reality. In these cases, the equipment would be constructed of cheaper carbon steel. Stainless steel is a good estimation for the flash drums and reactors, however, because those vessels would be processing either sterile fermentation materials or potentially corrosive chemicals.

When sizing the heat exchangers in the process, the APEA occasionally encountered an error in which the default specified heat transfer area of the exchanger differed by more than 10% from the required heat transfer area calculated from the simulation. In these cases, the heat transfer area calculated by Aspen was copied and the default equipment sizing area was replaced with the calculated area to alleviate the error.

The prices of all input and output streams were entered into the APEA using information collected from both the Independent Chemical Information Service (ICIS) and commodity chemicals company websites.

# 7.3 Full Process Diagram

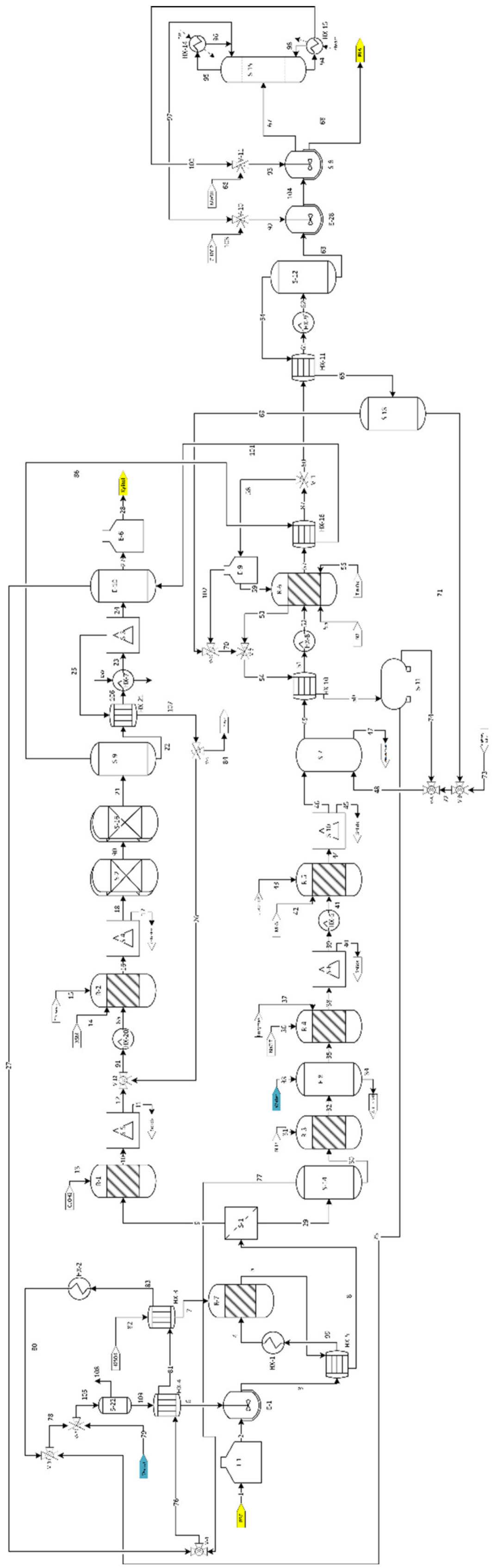


*Figure 7.3 – Full Process Diagram*

*Process Sections Indicated*

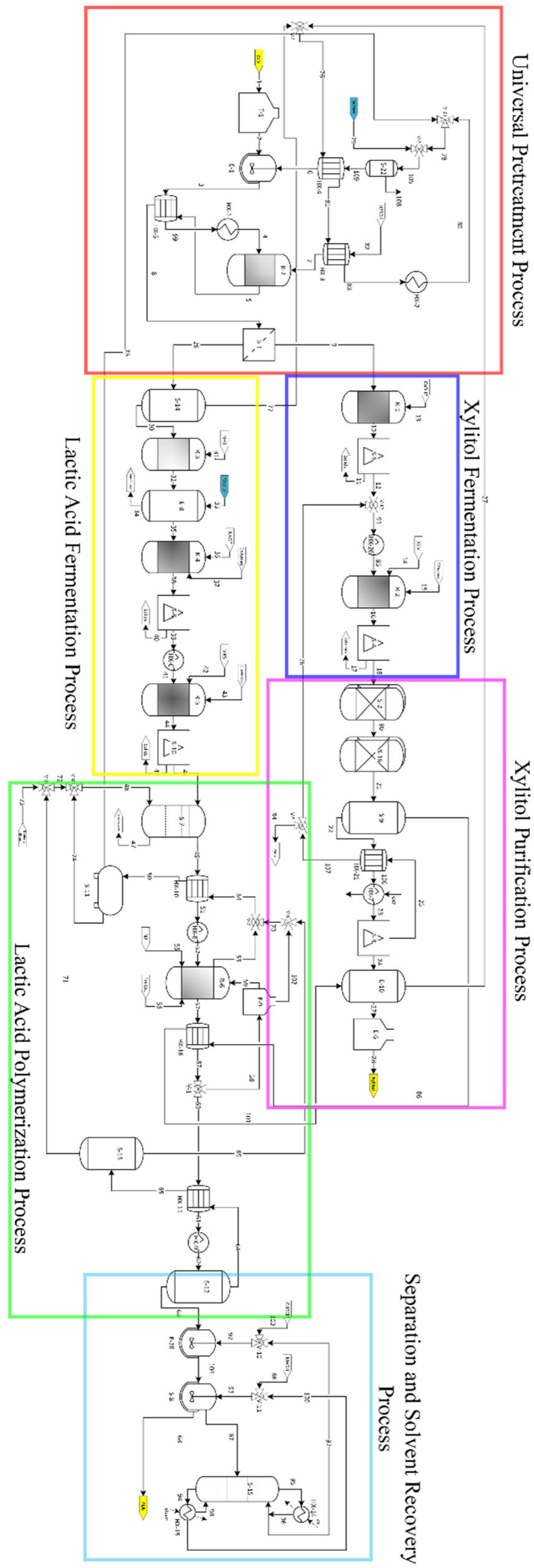



*Figure 7.4 – Full Process Diagram with Labelled Sections.*

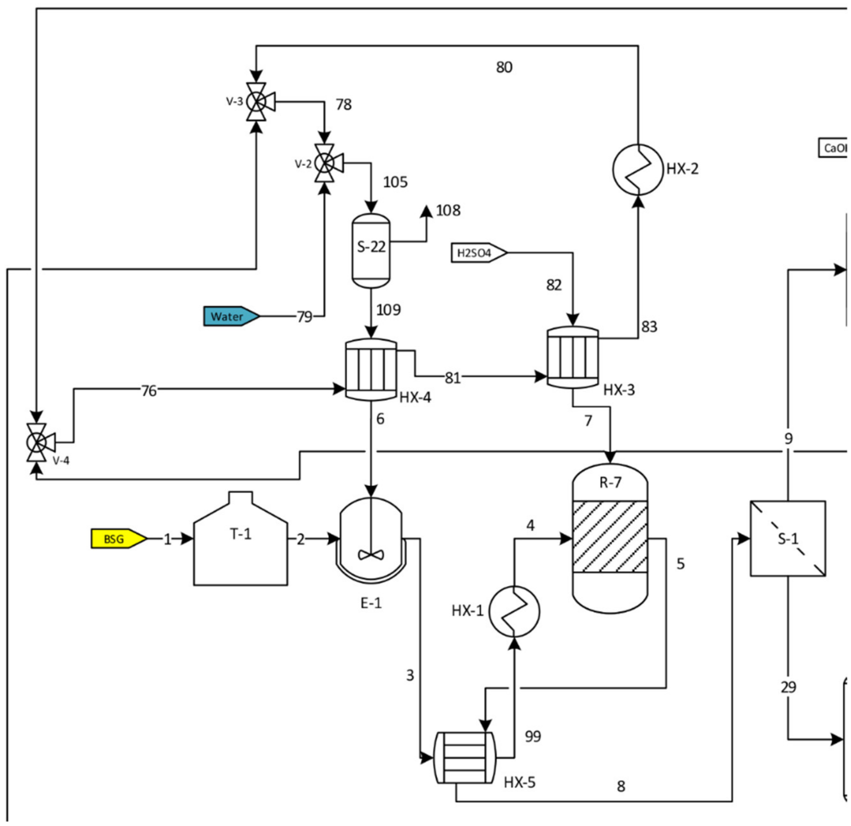
## Global Stream Balance

*Table 7.1 – Global Stream Report*

| Stream ID | 1.00 | 11.00 | 13.00 | 17.00 | 28.00 | 40.00 | 45.00 | 68.00 | 73.00 | 79.00 | 82.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature (°C)** | 25.00 | 25.00 | 25.00 | 32.00 | 5.00 | 25.00 | 37.00 | 25.85 | 25.00 | 25.00 | 25.00 |
| **Pressure (atm)** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Total Flow** | 160512.00 | 4465.88 | 7388.62 | 1338.15 | 9876.54 | 51682.60 | 1391.28 | 10660.10 | 14.80 | 200390.00 | 2351.00 |
| **Thermodynamics** | | | | | | | | | | | |
| *Enthalpy (J/kg)* | -12501100.00 | -13679300.00 | -14898400.00 | -5626300.00 | -7019930.00 | -10690100.00 | -5611900.00 | 0.00 | - | -16034300.00 | -11822800.00 |
| *Entropy (cal/g*K)* | -1.96 | -4.58 | -1.90 | -1.65 | -1.52 | -2.77 | -1.64 | 0.00 | - | -2.27 | -1.61 |
| **Composition** | | | | | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | 0.16 | - | - | - | - | - |
| *Ca(OH)2* | - | 0.01 | 0.14 | - | - | - | - | - | - | - | - |
| *CaSO4* | - | 0.40 | - | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | 0.39 | - | - | - | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - | - | - | - | - | - | - |
| *Enzymes* | - | - | - | - | 1.00 | 0.30 | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | - | - | - | - | - | 1.00 | - | - |
| *Ferment. Sugars* | - | - | - | - | - | - | - | - | - | - | - |
| *Lactic Acid* | - | - | - | - | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - | - | - | - | - |
| *Other Solids* | - | - | - | 1.00 | - | 0.07 | 1.00 | - | - | - | - |
| *Other Solutes* | - | - | - | - | - | - | - | - | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | 1.00 | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | 0.10 | - | - | - | - | - |
| *Sulfuric Acid* | - | 0.02 | - | - | - | - | - | - | - | - | 0.57 |
| *Water* | 0.61 | 0.58 | 0.86 | - | - | 0.36 | - | - | - | 1.00 | 0.43 |
| *Xylitol* | - | - | - | - | 1.00 | 0.30 | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - | - | - | - | - | - |

# 7.4 Process Description

### 7.4.1 Universal Pretreatment Process




| Equipment List | |
|---|---|
| ***Displayed Text*** | ***Function*** |
| E-1 | Wet BSG Input Wash |
| HX-1 | Makeup Wet BSG Heater |
| HX-2 | Steam Recycle Condenser |
| HX-3 | Inlet Sulfuric Acid Heat Exchanger |
| HX-4 | Inlet Water Heat Exchanger |
| HX-5 | Inlet Sulfuric Acid Heat Exchanger |
| R-7 | Acid Hydrolysis Reactor |
| S-1 | Pretreatment Filter |
| S-22 | Carbon Scrubbing Column |
| T-1 | Wet BSG Holding Tank |

*Figure 7.5 – Universal Pretreatment Process Flow Diagram*

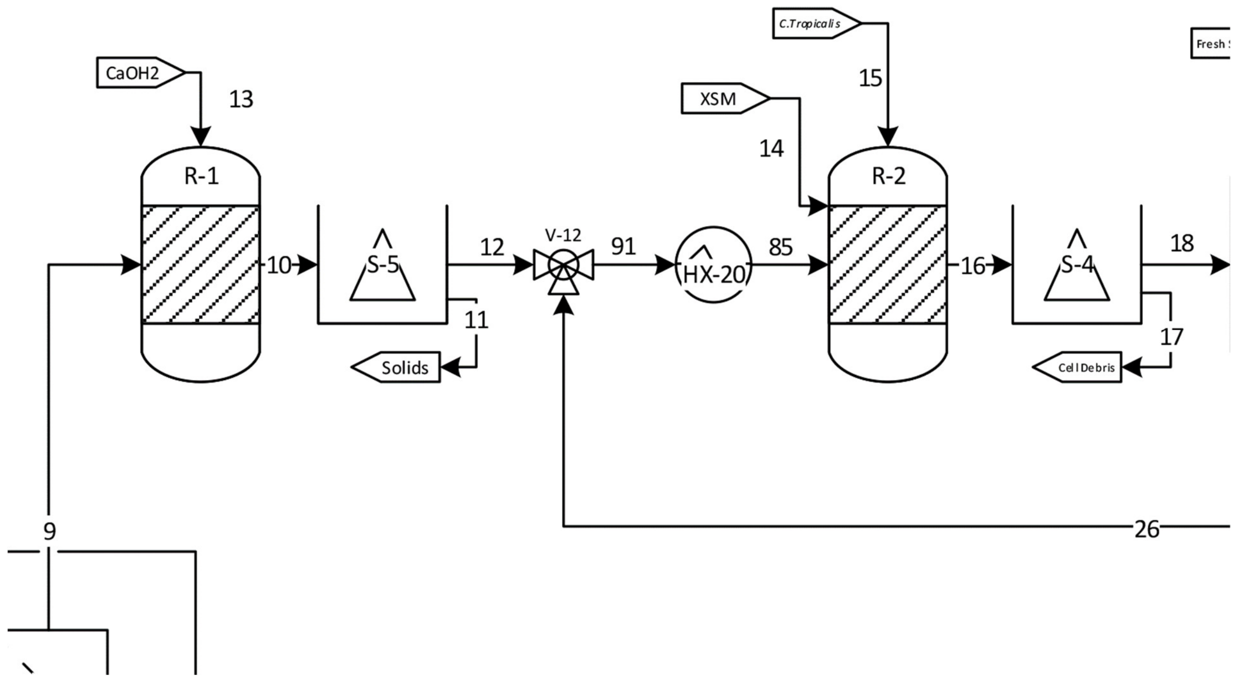
*Table 7.2 – Stream Report for Universal Pretreatment Process*

| Stream ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|
| Temperature (°C) | 25.00 | 25.00 | 75.90 | 150.00 | 150.00 | 95.00 | 92.00 | 102.78 | 102.78 | 102.78 |
| Pressure (atm) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total Flow | 160,512 | 160,512 | 516,332 | 516,332 | 518,683 | 355,802 | 2,351 | 518,683 | 165,777 | 352,906 |
| Thermodynamics | | | | | | | | | | |
| *Enthalpy (J/kg)* | -12,501,100 | -12,501,100 | -14,703,000 | -12,415,600 | -12,698,400 | -15,696,700 | -11,603,100 | -14,953,500 | -14,675,400 | -14,563,600 |
| *Entropy (cal/g*K)* | -1.96 | -1.96 | -2.00 | -0.55 | -0.46 | -2.02 | -1.45 | -1.89 | -1.86 | -1.58 |
| Composition | | | | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - | - | - | - | - |
| $Ca(OH)_2$ | - | - | - | - | - | - | - | - | - | - |
| $CaSO_4$ | - | - | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | 0.39 | 0.39 | 0.12 | 0.12 | 0.03 | - | - | 0.03 | - | 0.04 |
| $CH_2Cl_2$ | - | - | - | - | - | - | - | - | - | - |
| *Enzymes* | - | - | - | - | - | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | - | - | - | - | - | - | - |
| *Ferment. Sugars* | - | - | 0.00 | 0.00 | 0.00 | - | - | 0.00 | 0.00 | - |
| *Lactic Acid* | - | - | - | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - | - | - | - |
| $N_2$ | - | - | - | - | - | - | - | - | - | - |
| *Other Solids* | - | - | - | - | 0.01 | - | - | 0.01 | - | 0.01 |
| *Other Solutes* | - | - | - | - | 0.06 | - | - | 0.06 | 0.18 | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | 0.00 | - | 0.57 | 0.00 | 0.01 | - |
| *Water* | 0.61 | 0.61 | 0.88 | 0.88 | 0.88 | 1.00 | 0.43 | 0.88 | 0.73 | 0.95 |
| *Xylitol* | - | - | - | - | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | 0.02 | - | - | 0.02 | 0.08 | - |

| Stream ID | 75 | 76 | 79 | 80 | 81 | 83 | 99 | 105 | 108 | 109 |
|---|---|---|---|---|---|---|---|---|---|---|
| Temperature (°C) | 90.00 | 145.12 | 25.00 | 102.44 | 102.46 | 102.46 | 140.00 | 58.83 | 58.83 | 58.83 |
| Pressure (atm) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total Flow | 2,765 | 152,716 | 200,390 | 152,717 | 152,716 | 152,716 | 516,332 | 355,871 | 70 | 355,802 |
| Thermodynamics | | | | | | | | | | |
| *Enthalpy (J/kg)* | -15,720,900 | -13,195,700 | -16,034,300 | -15,655,800 | -13,602,800 | -13,606,200 | -12,437,600 | -15,869,400 | -5,548,940 | -15,871,400 |
| *Entropy (cal/g*K)* | -2.04 | -0.44 | -2.27 | -2.00 | -0.69 | -0.70 | -0.56 | -2.14 | -1.59 | -2.14 |
| Composition | | | | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - | - | - | - | - |
| $Ca(OH)_2$ | - | - | - | - | - | - | - | - | - | - |
| $CaSO_4$ | - | - | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - | 0.12 | - | - | - |
| $CH_2Cl_2$ | - | - | - | - | - | - | - | - | - | - |
| *Enzymes* | - | - | - | - | - | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | - | - | - | - | - | - | - |
| *Ferment. Sugars* | - | - | - | - | - | - | 0.00 | - | - | - |
| *Lactic Acid* | - | - | - | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - | - | - | - |
| $N_2$ | - | - | - | - | - | - | - | - | - | - |
| *Other Solids* | - | 0.00 | - | 0.00 | 0.00 | 0.00 | - | 0.00 | 1.00 | - |
| *Other Solutes* | - | - | - | - | - | - | - | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - | - | - | - | - |
| *Water* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.88 | 1.00 | - | 1.00 |
| *Xylitol* | - | - | - | - | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - | - | - | - | - |

A stream of ~63 wt.% water solid BSG enters in stream 1. The estimated flow rate of this stream is 160,512 kg/day. The stream first enters a holding tank (T-1) so that the discrete inputs of the BSG are smoothed out for a continuous process. After exiting the holding tank, the wet BSG stream enters an agitated washing tank (E-1) where it is combined with 355,801 kg/day of municipal and recycled water at 95°C heated by a recycle steam stream from later in the process (HX-4). The washing tank is stainless steel SS304, with a diameter of 1.06 meters and a tangent-to-tangent height of 4.42 meters. The washing tank holds a volume of 3950 L. The wash step increases the water content of the stream to 88% water to ensure that the wet BSG stream contains the right liquid to solid ratio as it enters the acid hydrolysis reactor (R-7). Before entering the reactor, the stream is heated by a product-to-feed heat exchanger (HX-5) to 140°C and then a furnace to 150°C (HX-1). 2351 kg/day of 57.5 wt.% sulfuric acid solution is heated to 92°C (HX-3) and added to the reactor to create a liquid to solid ratio of 8 g liquid/8 g solid. The reactor is a jacketed, agitated stainless steel SS304 tank. The residence time of the reactor is 1.5 hours, leading to a reactor volume of 28,334 liters. The vessel has a diameter of 5.49 meters and a tangent-to-tangent height of 19.2 meters. In this acid hydrolysis reactor, the hemicellulosic solids in the BSG are broken down into xylose, arabinose and glucose fermentable sugars along with other soluble by-products. The product stream (5) consists of 15,304 kg/day solid cellulose, 3903 kg/day other solids, 455,355 kg/day water, 12,949 kg/day fermentable sugars modelled as xylose, and 29,801 kg/day of other liquids. The stream is cooled from 150°C to 103°C in the feed-to-product heat exchanger used to heat the feed (HX-5) and then enters a rotary drum filter (S-1). The filter is a high-rate, SS316 rotary drum filter that is designed to separate the cellulose and other BSG solids from the acid hydrolysis slurry product stream (8). The filter is calibrated to reduce the water content of the solid stream to 95 wt.% water so as to avoid adding additional water to the stream later in the process. The solid stream from the filter (29) continues on to the lactic acid fermentation process and the liquid stream (9) continues to the xylitol fermentation process.

### 7.4.2 Xylitol Fermentation Process




| Equipment List | |
|---|---|
| ***Displayed Text*** | ***Function*** |
| HX-20 | Lactic Acid Feed Heat Exchanger |
| R-1 | Alkaline Hydrolysis |
| R-2 | Ethanol Fermenter |
| S-4 | Centrifuge 2 |
| S-5 | Centrifuge 1 |

*Figure 7.6 – Xylitol Fermentation Process Flow Diagram*

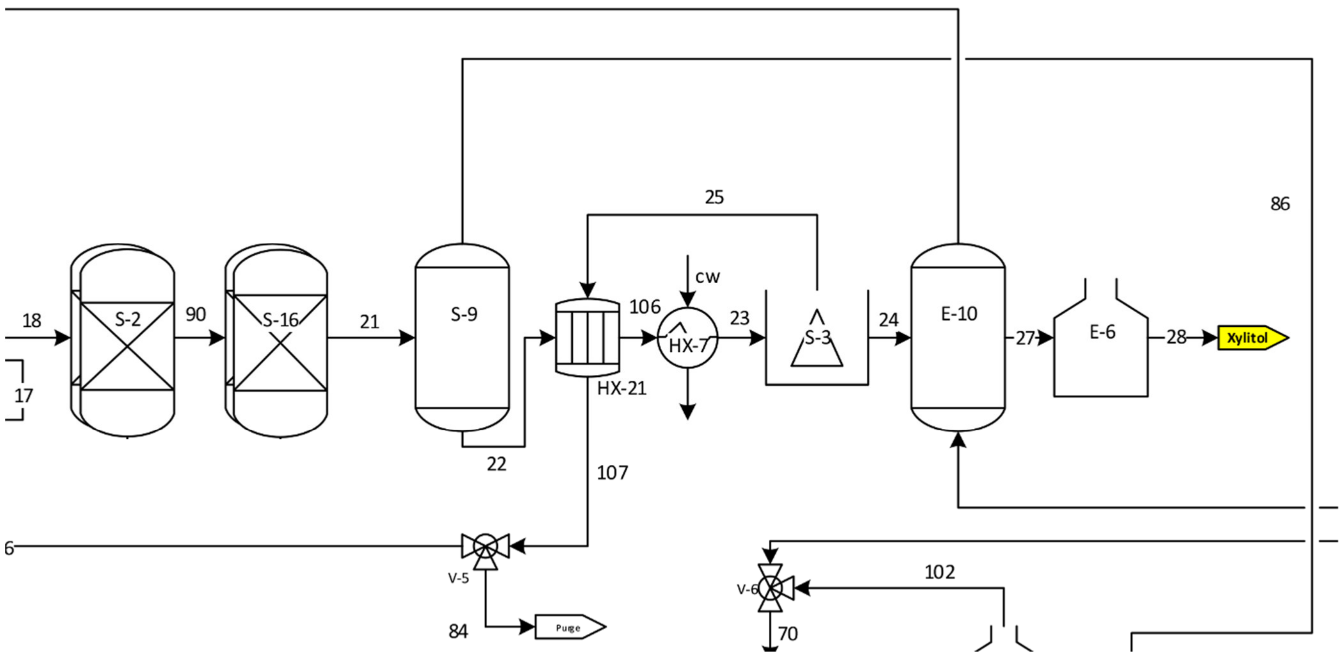
*Table 7.3 – Stream Report for Xylitol Fermentation Process*

| | | | | | |
|---|---|---|---|---|---|
| **Pressure (atm)** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Total Flow** | 165,777 | 173,166 | 4,466 | 168,700 | 7,389 |
| **Thermodynamics** | | | | | |
| *Enthalpy (J/kg)* | -14,675,400 | -15,056,900 | -13,679,300 | -15,102,500 | -14,898,400 |
| *Entropy (cal/g*K)* | -1.86 | -2.18 | -4.58 | -2.13 | -1.90 |
| **Composition** | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - |
| *Ca(OH)2* | - | 0.00 | 0.01 | - | 0.14 |
| *CaSO4* | - | 0.01 | 0.40 | - | - |
| *Cellulose Solid* | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - |
| *Enzymes* | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | - | - |
| *Ferment. Sugars* | 0.00 | 0.00 | - | 0.00 | - |
| *Lactic Acid* | - | - | - | - | - |
| *Methanol* | - | - | - | - | - |
| *N2* | - | - | - | - | - |
| *Other Solids* | - | - | - | - | - |
| *Other Solutes* | 0.18 | 0.17 | - | 0.18 | - |
| *Polylactic Acid* | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - |
| *Sulfuric Acid* | 0.01 | 0.00 | 0.02 | - | - |
| *Water* | 0.73 | 0.74 | 0.58 | 0.75 | 0.86 |
| *Xylitol* | - | - | - | - | - |
| *Xylose* | 0.08 | 0.07 | - | 0.08 | - |

| Stream ID | 16 | 17 | 18 | 85 | 91 |
|---|---|---|---|---|---|
| **Temperature (°C)** | 32.00 | 32.00 | 32.00 | 32.00 | 27.22 |
| **Pressure (atm)** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Total Flow** | 175,104 | 1,338 | 173,766 | 175,104 | 175,104 |
| **Thermodynamics** | | | | | |
| *Enthalpy (J/kg)* | -15,009,000 | -5,626,300 | -15,081,200 | -15,012,000 | -15,033,500 |
| *Entropy (cal/g*K)* | -2.09 | -1.65 | -2.10 | -2.10 | -2.11 |
| **Composition** | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - |
| *Enzymes* | 0.07 | - | 0.07 | 0.00 | 0.00 |
| *Diphenyl Ether* | - | - | - | - | - |
| *Ferment. Sugars* | - | - | - | 0.00 | 0.00 |
| *Lactic Acid* | - | - | - | - | - |
| *Methanol* | - | - | - | - | - |
| *N2* | - | - | - | - | - |
| *Other Solids* | 0.01 | 1.00 | - | - | - |
| *Other Solutes* | 0.17 | - | 0.17 | 0.17 | 0.17 |
| *Polylactic Acid* | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - |
| *Water* | 0.75 | - | 0.75 | 0.75 | 0.75 |
| *Xylitol* | 0.07 | - | 0.07 | 0.00 | 0.00 |
| *Xylose* | 0.01 | - | 0.01 | 0.08 | 0.08 |

The stream of fermentable sugars and inert solutes (9) from the rotary drum filter (S-1) first enters a neutralization reactor (R-1). The neutralization reactor is a stainless steel SS304 agitated, jacketed vertical tank with a diameter of 0.76 meters and a tangent-to-tangent height of 7.77 meters. The neutralization process requires the reactor to have a residence time of 30 minutes, leading to a vessel volume of 7,656 liters. 7,389 kg/day of 2.00 molar $CaOH_2$ solution is added to the reactor in order to neutralize the acid hydrolysis product from a pH of approximately 1.25 to a pH of ~2.5. The pH of 2.5 is the ideal pH required by the *C. tropicalis* bacterium used in the fermentation. In the neutralization reaction, the hydroxide ions in the $CaOH_2$ solution react with the hydronium ions released by the $H_2SO_4$ in the acid hydrolysis reactor (R-7) to produce water and calcium sulfate (CaSO4). The calcium sulfate is insoluble in water and precipitates out of the solution as a solid. A continuous disk centrifuge (S-5) with a diameter of 0.254 meters processes the reactor effluent and separates the calcium sulfate solids from the neutralized liquid stream. The liquid stream is first mixed with a 92°C recycle stream from later in the process that heats the combined stream from 25°C to 27°C. The stream is then further heated to 32°C using municipal steam (HX-20), and is fed to the continuous xylose fermenter (R-2) at 80 g/L xylose. The fermenter contains *Candida tropicalis* yeast kept in a continuous growth stage that ferment the sugars in the liquid feed into xylitol. The yeast are grown in separate scale-up tanks before being added to the fermenter along with Yeast Mold broth. The fermenter is modeled as a stainless steel, ideal anaerobic well-mixed chemostat with an optimal dilution rate of 0.084 $h^{-1}$. This gives a residence time of 12 hours and a volume of approximately 62,000 liters. The fermenter is cooled with chilled water to counter the heat generated through the fermentation process. The broth is continuously drained along with the yeast, and all goes to the subsequent purification steps

### 7.4.3 Xylitol Purification Process




| Equipment List | |
|---|---|
| ***Displayed Text*** | ***Function*** |
| E-10 | Crystal Wash |
| E-6 | Dryer |
| HX-21 | Inlet Sulfuric Acid Heat Exchanger |
| HX-7 | Condenser |
| S-16 | Anion Chromatography Column |
| S-2 | Cation Chromatography Column |
| S-3 | Centrifuge 2 |
| S-9 | Evaporator |

*Figure 7.7 – Xylitol Purification Process Flow Diagram*

*Table 7.4 – Xylitol Purification Process Stream Report*

| Stream ID | 18 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|
| Temperature (°C) | 32.00 | 32.00 | 103.30 | 5.00 | 5.00 | 5.00 | 95.00 | 155.20 |
| Pressure (atm) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total Flow | 173,766 | 143,964 | 25,010 | 25,010 | 12,203 | 12,808 | 6,404 | 118,953 |
| Thermodynamics | | | | | | | | |
| *Enthalpy (J/kg)* | -15,081,200 | -15,140,000 | -10,864,400 | -11,176,100 | -8,706,240 | -13,573,500 | -13,215,700 | -13,180,600 |
| *Entropy (cal/g*K)* | -2.10 | -2.15 | -1.62211 | -1.85 | -1.64 | -2.09 | -1.82 | -0.43 |
| Composition | | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - | - | - | - |
| *Enzymes* | 0.07 | 0.08 | 0.46 | 0.46 | 0.81 | 0.14 | 0.14 | - |
| *Diphenyl Ether* | - | - | - | - | - | - | - | - |
| *Ferment. Sugars* | - | - | - | - | - | - | - | - |
| *Lactic Acid* | - | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - | - |
| *Other Solids* | - | - | - | - | - | - | - | - |
| *Other Solutes* | 0.17 | - | - | - | - | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - | - | - |
| *Water* | 0.75 | 0.91 | 0.47 | 0.47 | 0.19 | 0.73 | 0.73 | 1.00 |
| *Xylitol* | 0.07 | 0.08 | 0.46 | 0.46 | 0.81 | 0.14 | 0.14 | - |
| *Xylose* | 0.01 | 0.01 | 0.07 | 0.07 | - | 0.14 | 0.14 | - |

| Stream ID | 28 | 69 | 84 | 86 | 89 | 106 | 107 |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | 5.00 | 157.48 | 95.00 | 103.30 | 32.00 | 45.92 | 95.00 |
| Pressure (atm) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total Flow | 9,877 | 2,740 | 6,404 | 118,953 | 29,802 | 25,010 | 12,808 |
| Thermodynamics | | | | | | | |
| *Enthalpy (J/kg)* | -7,019,930 | -8,417,330 | -13,215,700 | -13,280,000 | -14,798,200 | -11,047,700 | -13,215,700 |
| *Entropy (cal/g*K)* | -1.52 | -0.42 | -1.82 | -0.49 | -2.09 | -1.75 | -1.82 |
| Composition | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - | - | - |
| *Enzymes* | 1.00 | - | 0.14 | - | - | 0.46 | 0.14 |
| *Diphenyl Ether* | - | 0.35 | - | - | - | - | - |
| *Ferment. Sugars* | - | - | - | - | - | - | - |
| *Lactic Acid* | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - |
| *Other Solids* | - | - | - | - | - | - | - |
| *Other Solutes* | - | - | - | - | 1.00 | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - | - |
| *Water* | - | 0.65 | 0.73 | 1.00 | - | 0.47 | 0.73 |
| *Xylitol* | 1.00 | - | 0.14 | - | - | 0.46 | 0.14 |
| *Xylose* | - | - | 0.14 | - | - | 0.07 | 0.14 |

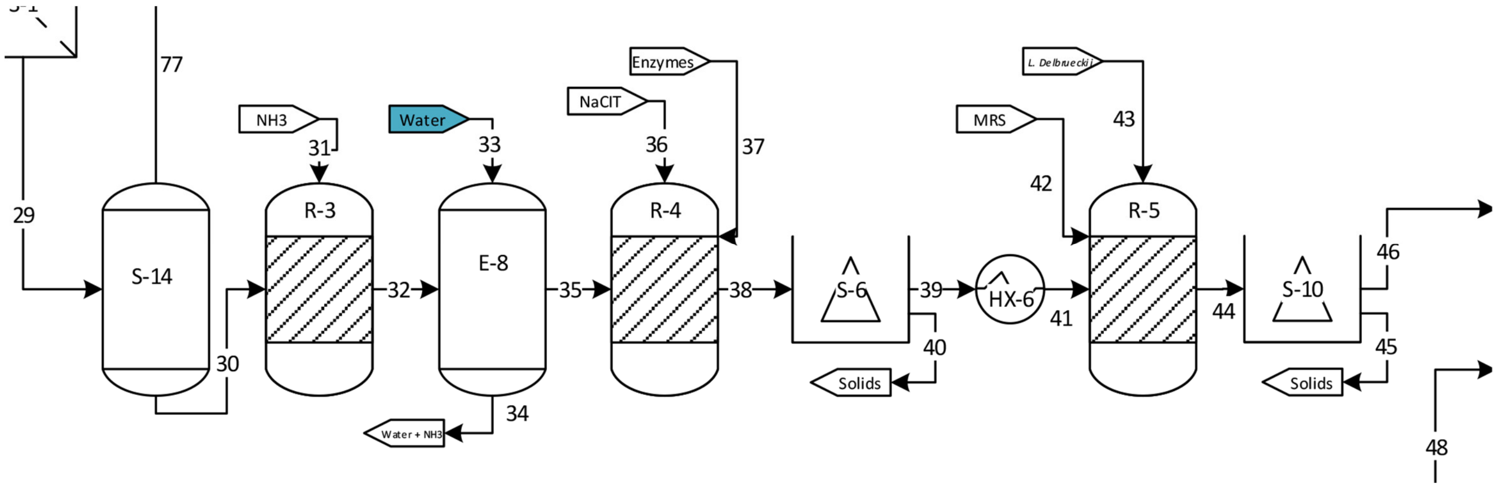
The xylitol purification process, as outlined, obtains pure (99.9%) crystalline xylitol from fermentation product. The process is entirely continuous, in line with the rest of the process design. The fermentation product stream (16) is fed through a continuous centrifuge (S-4) that separates out any solid suspended cell debris solids before the liquid stream passes into two chromatography columns (S-2) and (S-16). The centrifuge is also able to kill some of the *C. tropicalis*, which is a human pathogen. The solid stream exiting the centrifuge is discarded, treated for impurities, and combined with the wastewater removal. The liquid stream (18) continues through the purification process at a flowrate of 173,766 kg/day.

The stream that enters the first chromatography column is assumed to be 50-75% weight xylitol, less than 5% xylose, and water. Both columns are ion exchange resins, which work by containing a polymer that captures ions of interest and removes them from the solution. The first chromatography column is a CS 14 GC cationic ion exchange resin. It is able to remove all inorganic salts and a large portion of organic impurities. The column is modeled as a polystyrene sulfonic resin, 5 meters high and 2.5 meters in diameter, and uses cross-coupled divinyl benzene as a solvent. The second chromatography column is a 103S vinylbenzyl tertiary anion exchange resin. The purpose of this column is to remove the rest of the organic impurities and balance the color of the solution. It is the same size of the first column, at 5 meters high and 2.5 meters tall. Due to the high salinity of the fermentation product, and the need for regeneration, the system will have an additional cation exchange resin and anion exchange resin to be used when the primary columns need to regenerate. The regeneration will occur when about 80% of the adsorption sites within the column are full of salt.

After the two continuous chromatography columns, the effluent stream is colorless, aqueous xylitol and xylose solution with no other impurities. Its flowrate is 143,964 kg/day. The stream (21) is then fed into an evaporator (S-9) at 106°C until nearly all water is removed. For fractional crystallization, the liquid mixture of xylitol and xylose is then cooled to 5°C in the crystallizer (S-3), at which point nearly all of the xylitol is crystallized. The flow rate entering the crystallizer is 25,010 kg/day. The mother liquor that remains is conveniently recycled back into the stream entering the xylitol fermenter, as the stream contains some xylose that may be broken down to xylitol. The addition of this recycle streams allows at least 95% of total liquid xylitol to crystalize in this process. The final crystalline product is 99.9 weight percent xylitol, making it food grade quality.

The crystalline xylitol is fed into a wash drum (E-10) at 12,203 kg/day to be steam sterilized at 134°C for 3 minutes. This process removes any possibility of *C. tropicalis* in the final product. The crystalline xylitol in then dried and packaged to be sold. The final production of xylitol is 9,876 kg/day. This process was designed using the outlined processes in US patents 3985815 and 4008285.

### 7.4.4 Lactic Acid Fermentation Process




| Equipment List | |
|---|---|
| ***Displayed Text*** | ***Function*** |
| E-8 | AAS Wash |
| HX-6 | Condenser |
| R-3 | AAS Reactor |
| R-4 | Saccarification Reactor |
| R-5 | Lactic Acid Fermenter |
| S-10 | Fermenter Product Centrifuge |
| S-14 | Lactic Acid Pretreatment Evaporator |
| S-6 | Solid Centrifuge |

*Figure 7.8 –Lactic Acid Fermentation Process Flow Diagram*

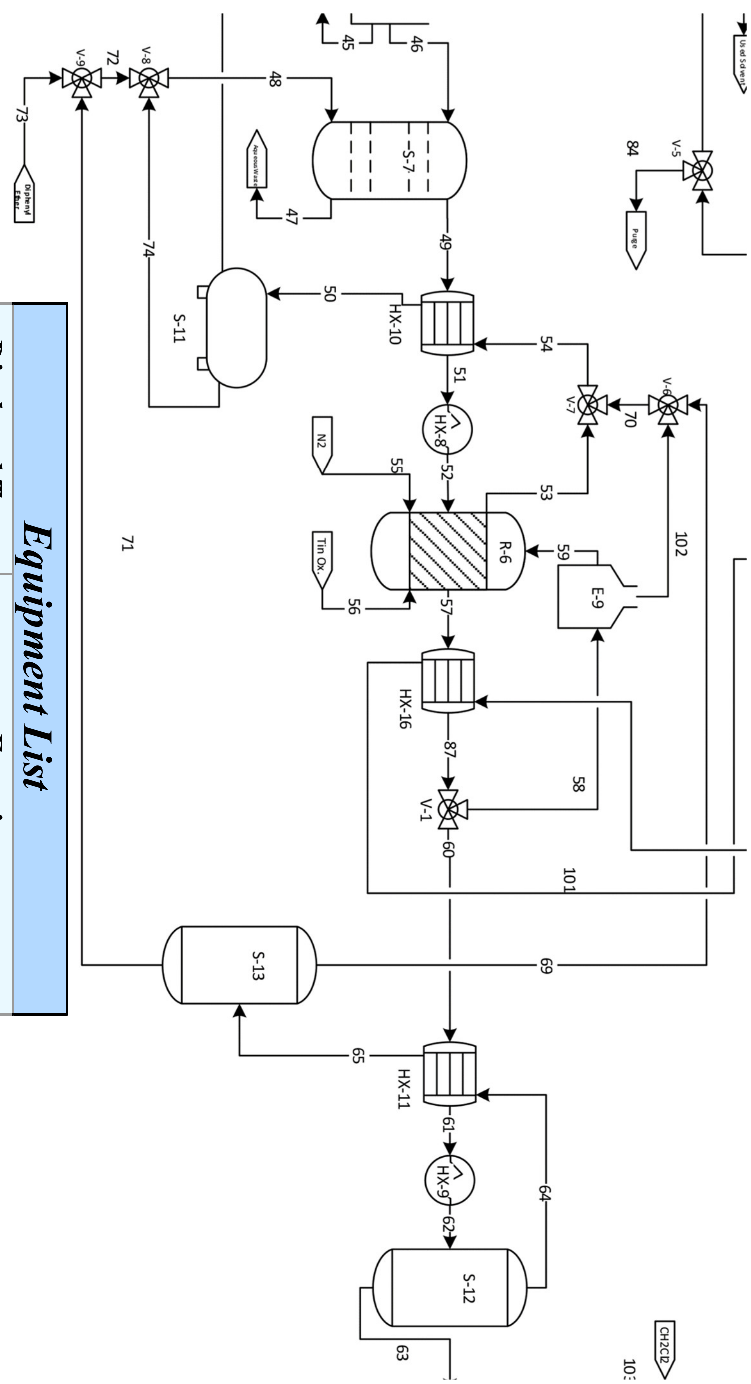
*Table 7.5 – Lactic Acid Fermentation Process Stream Report*

| Stream ID | 2 | 30 | 31 | 32 | 33 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|---|---|---|---|
| **Temperature (°C)** | 25.00 | 110.00 | 25.00 | 70.00 | 25.00 | 64.79 | 25.00 | 25.00 | 25.00 |
| **Pressure (atm)** | 1.00 | 1.30 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Total Flow** | 160,512 | 319,143 | 29,990 | 349,133 | 50,000 | 399,133 | 5,201 | 15,671 | 420,005 |
| **Thermodynamics** | | | | | | | | | |
| *Enthalpy (J/kg)* | -12,501,100 | -15,070,700 | -14,470,700 | -15,511,400 | -16,034,300 | -15,576,900 | -7,627,540 | -6,983,490 | -15,053,100 |
| *Entropy (cal/g*K)* | -1.96 | -1.93 | -3.97 | -2.21 | -2.27 | -2.22 | -0.53 | -1.49 | -2.30 |
| **Composition** | | | | | | | | | |
| *Ammonium Hydr.* | - | - | 0.28 | 0.02 | - | 0.02 | - | - | 0.02 |
| *Ca(OH)2* | - | - | - | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | 0.39 | 0.05 | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - | - | - | - | - |
| *Enzymes* | - | - | - | - | - | - | - | 1.00 | 0.04 |
| *Diphenyl Ether* | - | - | - | - | - | - | - | - | - |
| *Ferment. Sugars* | - | - | - | - | - | - | - | - | 0.04 |
| *Lactic Acid* | - | - | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - | - | - |
| *Other Solids* | - | 0.01 | - | 0.01 | - | 0.01 | - | - | 0.01 |
| *Other Solutes* | - | - | - | 0.04 | - | 0.04 | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | - | 1.00 | - | 0.01 |
| *Sulfuric Acid* | - | - | - | - | - | - | - | - | - |
| *Water* | 0.61 | 0.94 | 0.72 | 0.92 | 1.00 | 0.93 | - | - | 0.88 |
| *Xylitol* | - | - | - | - | - | - | - | 1.00 | 0.04 |
| *Xylose* | - | - | - | - | - | - | - | - | - |

| Stream ID | 39 | 40 | 41 | 44 | 45 | 46 | 47 | 77 |
|---|---|---|---|---|---|---|---|---|
| **Temperature (°C)** | 25.00 | 25.00 | 37.00 | 37.00 | 37.00 | 37.00 | 22.70 | 110.00 |
| **Pressure (atm)** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.30 |
| **Total Flow** | 368,323 | 51,683 | 368,323 | 368,323 | 1,391 | 366,931 | 353,084 | 33,763 |
| **Thermodynamics** | | | | | | | | |
| *Enthalpy (J/kg)* | -15,665,400 | -10,690,100 | -15,608,400 | -15,617,900 | -5,611,900 | -15,655,900 | -16,034,500 | -13,249,000 |
| *Entropy (cal/g*K)* | -2.23 | -2.77 | -2.19 | -2.35 | -1.64 | -2.35 | -2.28 | -0.51 |
| **Composition** | | | | | | | | |
| *Ammonium Hydr.* | - | 0.16 | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - | - | - | - |
| *Enzymes* | - | 0.30 | - | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | - | - | - | - | - |
| *Ferment. Sugars* | 0.04 | - | 0.04 | 0.00 | - | 0.00 | - | - |
| *Lactic Acid* | - | - | - | 0.04 | - | 0.04 | 0.00 | - |
| *Methanol* | - | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - | - |
| *Other Solids* | - | 0.07 | - | 0.00 | 1.00 | - | - | 0.00 |
| *Other Solutes* | - | - | - | - | - | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | - |
| *Sodium Citrate* | - | 0.10 | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - | - | - |
| *Water* | 0.96 | 0.36 | 0.96 | 0.96 | - | 0.96 | 1.00 | 1.00 |
| *Xylitol* | - | 0.30 | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - | - | - |

The solid stream from the acid hydrolysis product filter (29) first enters an evaporator (S-14) that heats it to 110°C using medium pressure steam. It was assumed that the solids separated by filter S-1 contained 95.4 wt.% water. 33,693 kg/day of this water is vaporized in the evaporator and is recycled as heating steam (77). A design specification was used to ensure that the evaporator removes enough water from the stream so that the fermenter feed stream contains glucose sugars at a concentration of 50 g/L. The dried solids are removed from the evaporator at 110°C and fed to the aqueous ammonia soaking (AAS) reactor (R-3) along with 29,990 kg/day of 25°C 28 wt.% ammonium hydroxide solution in water. The AAS reactor is a 27,789 liter jacketed, agitated stainless steel SS304 vertical vessel with a residence time of 22 hours. The vessel has a diameter of 2.13 meters and a tangent-to-tangent height of 7.77 meters. The combining streams entering the reactor equilibrate to a temperature of 70°C while the AAS reaction occurs. The treated solids are fed to a vertical stainless steel wash vessel (E-8) where they are mixed with 50,000 kg/day of 25°C municipal water in order to neutralize the stream. Excess basic free water in the vessel is removed and disposed as a waste stream (34). The washed, processed solids are fed to a saccharification reactor at 25°C (R-4) along with 5,201 kg/day of pH 5.5 sodium citrate buffer solution and 15,671 kg/day of cellulase enzymes. The saccharification reactor is a 2,602 liter stainless steel SS304 agitated, jacketed reactor that operates at a temperature of 25C. The reactor has a diameter of 0.91 meters, a tangent-to-tangent height of 3.96 meters and a residence time of 1.5 hours. In the saccharification reactor, the treated cellulose solids in the feed stream are broken down into glucose that dissolves into solution. It was assumed that there was 100% conversion of the cellulose solids in the reactor into aqueous glucose. Seven identical continuous disk centrifuges -- each with a diameter of 0.254 meters -- are run in parallel to remove the remaining solids in the reactor effluent stream (S-6) and the liquid is fed to a heat exchanger (HX-6). Low pressure steam is used to heat the stream to 37°C and it is fed into the continuous lactic acid fermentation bioreactor (R-5). The feed stream to the fermenter contains 383,551 kg/day of water and 36,177 kg/day of glucose. The fermentation reactor is a 95,000 liter agitated, jacketed vertical stainless steel SS304 vessel with a residence time of 10 hours. It is loaded with *Lactobacillus delbrueckii* at a concentration at 2 grams of cells per liter. The dilution rate is set equal to $0.1h^{-1}$ for optimal cell growth and product production. It is being modeled as an ideal, well-mixed continuous chemostat.  This will also have to be cooled with chilled water in order to counteract the heat associated with the fermentation.  All of the bacteria and broth will be flushed out to the subsequent purification steps.

### 7.4.5 Lactic Acid Polymerization and Purification Process




| Equipment List | |
|---|---|
| Displayed Text | Function |
| E-9 | PLA Recycle Drier |
| HX-10 | Lactic Acid Feed Heat Exchanger |
| HX-11 | Distillate to Bottoms Exchanger |
| HX-16 | Steam Stream Heat Exchanger |
| HX-8 | Heater |
| HX-9 | Heater |
| R-6 | Polymerization Reactor |
| S-11 | Water/Solvent Decanter |
| S-12 | Ether Separating Flash Drum |
| S-13 | Solvent Flash Drum |

*Figure 7.9 – Lactic Acid Polymerization Process Flow Diagram*

*Table 7.6 – Lactic Acid Polymerization Process Stream Report*

| Stream ID | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 54 | 57 | 58 | 59 | 60 | 61 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature (°C)** | 37.00 | 37.00 | 37.00 | 22.70 | 155.79 | 22.00 | 90.00 | 93.20 | 170.00 | 140.84 | 170.00 | 110.00 | 99.86 | 110.00 | 237.48 |
| **Pressure (atm)** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Total Flow** | 368,323 | 1,391 | 366,931 | 353,084 | 40,408 | 53,848 | 3,776 | 53,848 | 53,848 | 3,776 | 105,620 | 52,808 | 51,772 | 52,808 | 52,808 |
| **Thermodynamics** | | | | | | | | | | | | | | | |
| *Enthalpy (J/kg)* | -15,617,900 | -5,611,900 | -15,655,900 | -16,034,500 | 9,735 | -2,093,650 | -11,388,700 | -1,970,000 | -1,818,490 | -9,625,170 | -400,581 | -512,566 | -288,865 | -512,566 | -129,926 |
| *Entropy (cal/g*K)* | -2.35 | -1.64 | -2.35 | -2.28 | -0.63 | -2.04 | -1.57 | -1.95 | -1.86 | -0.44 | -0.48 | -0.54 | -0.56 | -0.54 | -0.34 |
| **Composition** | | | | | | | | | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Enzymes* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | - | 0.99 | 0.74 | 0.26 | 0.74 | 0.74 | 0.26 | 0.76 | 0.76 | 0.77 | 0.76 | 0.76 |
| *Ferment. Sugars* | 0.00 | - | 0.00 | - | 0.00 | 0.00 | - | 0.00 | 0.00 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Lactic Acid* | 0.04 | - | 0.04 | 0.00 | - | 0.25 | - | 0.25 | 0.25 | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Other Solids* | 0.00 | 1.00 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Other Solutes* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | - | - | - | - | - | 0.20 | 0.20 | 0.21 | 0.20 | 0.20 |
| *Sodium Citrate* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Water* | 0.96 | - | 0.96 | 1.00 | 0.01 | 0.01 | 0.74 | 0.01 | 0.01 | 0.74 | 0.04 | 0.04 | 0.02 | 0.04 | 0.04 |
| *Xylitol* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| Stream ID | 62 | 63 | 64 | 65 | 67 | 68 | 69 | 71 | 72 | 74 | 75 | 87 | 101 | 102 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature (°C)** | 288.00 | 288.00 | 288.00 | 180.00 | 25.85 | 25.85 | 157.48 | 157.48 | 157.48 | 90.00 | 90.00 | 110.00 | 155.20 | 99.86 |
| **Pressure (atm)** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Total Flow** | 52,808 | 10,671 | 42,137 | 42,137 | 116,169 | 10,660 | 2,740 | 39,397 | 39,397 | 1,010 | 2,765 | 105,620 | 118,953 | 1,036 |
| **Thermodynamics** | | | | | | | | | | | | | | |
| *Enthalpy (J/kg)* | 2,388 | -6,860 | 4,730 | -474,813 | -3,324,070 | 0 | -8,417,330 | 16,767 | 16,767 | -264,499 | -15,720,900 | -512,563 | -13,180,600 | -12,820,000 |
| *Entropy (cal/g*K)* | -0.28 | 0.00 | -0.35 | -0.58 | -0.88 | 0.00 | -0.42 | -0.63 | -0.63 | -0.70 | -2.04 | -0.54 | -0.43 | -0.49 |
| **Composition** | | | | | | | | | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *CH2Cl2* | - | - | - | - | 0.69 | - | - | - | - | - | - | - | - | - |
| *Enzymes* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Diphenyl Ether* | 0.76 | 0.00 | 0.95 | 0.95 | 0.00 | - | 0.35 | 0.99 | 0.99 | 0.98 | - | 0.76 | - | 0.03 |
| *Ferment. Sugars* | 0.00 | - | 0.00 | 0.00 | - | - | - | 0.00 | 0.00 | - | - | 0.00 | - | - |
| *Lactic Acid* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Methanol* | - | - | - | - | 0.31 | - | - | - | - | - | - | - | - | - |
| *N2* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Other Solids* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Other Solutes* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Polylactic Acid* | 0.20 | 1.00 | - | - | - | 1.00 | - | - | - | - | - | 0.20 | - | - |
| *Sodium Citrate* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Water* | 0.04 | - | 0.05 | 0.05 | - | - | 0.65 | 0.01 | 0.01 | 0.02 | 1.00 | 0.04 | 1.00 | 0.97 |
| *Xylitol* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

As in the xylitol purification process, the lactic acid fermentation product is fed to a continuous centrifuge (S-10) that separates any remaining solids and cell debris from the stream. The aqueous lactic acid solution is fed to a liquid liquid extraction column (S-7) at a temperature of 37°C and a rate of 366,931 kg/day. This lactic acid solution contains 353,019 kg/day of water, 139 kg/day of unfermented sugars, and 13,774 kg/day of lactic acid. A mostly-recycled solvent feed of 39,981 kg/day of diphenyl ether, 283 kg/day of residual water and 139 kg/day of glucose is mixed with enough makeup diphenyl ether to reach 40,000 kg/day and also fed into the extraction column at a temperature of 163C. The column is a stainless steel SS304, single-diameter vertical vessel with 10 equilibrium sieve trays. The column is clad in SS304 stainless steel. The raffinate stream contains trace amounts of diphenyl ether, 268,849 kg/day of water, 6167 kg/day of dissolved lactic acid and 330 kg/day of unfermented glucose and is discarded as waste. The extract stream contains 384 kg/day of water, 139 kg/day of glucose, and 13,325 kg/day of lactic acid dissolved in 40,000 kg/day of diphenyl ether solvent. The liquid extraction therefore removes approximately 96% of the lactic acid present in the fermentation product stream. The extract is fed to a heat exchanger (HX-10) and is heated with recycled diphenyl ether and water vapor (54) to a temperature of 93°C. High pressure steam is used to further heat the stream to 170°C (HX-8) and the stream is fed to the direct condensation polymerization reactor (R-6). The reactor is a SS304 stainless steel, 10,842 liter agitated and jacketed vessel with a retention time of 1.5 hours. The reaction vessel has a diameter of 1.524 meters and a tangent-to-tangent height of 5.94 meters. The design temperature of the reactor is 197°C. The polymerization reaction occurs at an operating temperature of 170°C over a bed of solid tin oxide catalyst. The catalyst does not require rejuvenation following the reaction and is therefore a permanent capital cost of the reactor. As little data was found regarding the exact amount of catalyst to use, it was assumed that the catalyst would form a 1-meter bed on the bottom of the reactor vessel. The reactor diameter and the density of tix oxide catalyst were used to estimate a catalyst mass of 12,678 kg of tin oxide. Nitrogen gas is continuously bubbled through the reactor to encourage mixing and to provide an inert environment for the condensation reaction to take place. During the reaction, two lactic acid monomers combine to create one 'link' of the polylactic acid polymer and release one molecule of water. This water does not dissolve in the diphenyl ether solvent and vaporizes. This water vapor stream is removed from the reactor (53) and mixed with other steam recycle streams (V-7) to provide heat for HX-10. The exit stream from the polymerization reactor is first fed to a heat exchanger (HX-16) at 170°C where it is used to heat the evaporated steam stream (86) from the xylitol purification evaporator (S-9) from 103°C to 155°C. The cooled polymerization reactor effluent, now at 110, is split equally using a splitter valve (V-1). Half of the reactor exit stream is fed to a flash evaporator (E-9) where it cools to 100°C as the water in the stream is separated as vapor.

The vapor stream contains 1000 kg/day of water vapor, 35 kg/day of diphenyl ether and trace glucose. It is mixed with a 157°C steam recycle generated further in the process (69) using a mixing valve (V-6) and the free water decant of the PLA reactor (53) and the combined stream reaches a temperature of 141°C. This stream is used as the hot stream in HX-10 to heat the lactic acid feed stream (49) from 35°C to 93°C before it enters the polymerization reactor (R-6). In the heat exchanger, the stream is cooled from 141°C to 90°C. Following the heat exchanger, the cooled stream contains 2,785 kg/day of water and 991 kg/day of diphenyl ether – it must be separated before either the water or diphenyl ether can be recycled. The stream is fed into a decanter (S-11) at 90°C where the water and diphenyl ether are separated. The decanter is a vertical, stainless steel SS304 processing vessel with a volume of 2401 liters. The decanter has a diameter of 0.914 meters and a tangent-to-tangent height of 3.66 meters. The second liquid stream from the decanter (74) contains 991 kg/day of 98 wt.% diphenyl ether and is mixed with both the pure diphenyl ether input stream (73) and another diphenyl ether recycle stream (71) originating later in the process. This combined stream (48) is then recycled as feed to the lactic acid liquid extraction column (S-7). The first liquid stream from the decanter (75) contains 2,765 kg/day of ~100 wt% pure water and is combined with the original BSG water input stream (79) using a mixing valve (V-3).

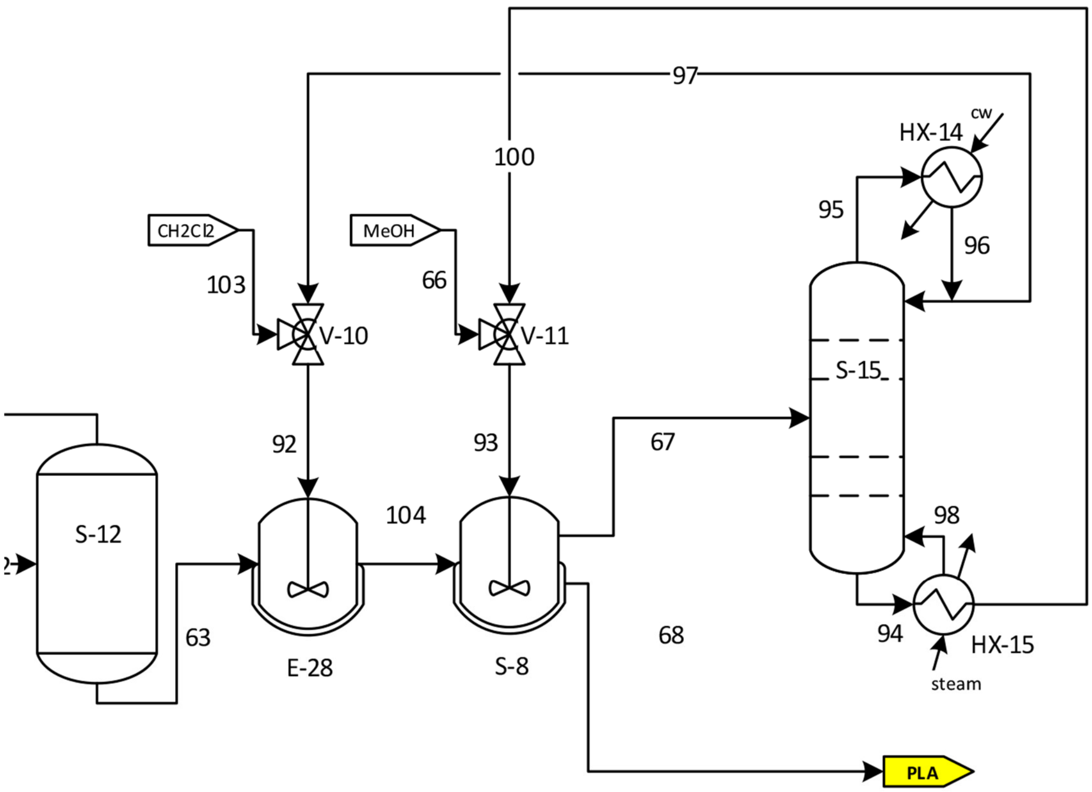
The cooled PLA liquid stream (59) is fed back into the polymerization reactor (R-6) where it gets heated back to 170°C and continues to participate in the lactic acid polymerization reaction. This recycle loop allows for the molecular weight of the PLA created in the reactor to be controlled. If a higher molecular weight polymer is required, a higher fraction of the reactor product stream can be split into the recycle loop by V-1 and vice versa for lower molecular weights of PLA.

The solvent and PLA stream that is not recycled (60) is heated to 237°C in a feed-to-top heat exchanger (HX-11) and then further heated to 288°C using high pressure steam (HX-9). The heated stream is fed to a flash vessel (S-12) that separates the diphenyl ether and water in the stream from the PLA. The flash vessel is a vertical, stainless steel SS304 vessel with a volume of 2402 liters. The flash vessel has a diameter of 0.914 meters and a tangent-to-tangent height of 3.66 meters. The flash is performed at a temperature of 288°C and the diphenyl ether vapor stream is used to preheat the feed as described previously. This preheating heat exchanger cools the diphenyl ether vapor stream from 288°C to 180°C.

The flash process removes almost all of the diphenyl ether from the feed stream, leading to a vapor stream of 39,946 kg/day of diphenyl ether mixed with 2,047 kg/day of water. In order to remove the water from this stream and recycle the diphenyl ether, the mixture is fed to another flash vessel (S-13) at 180°C where it cools to 157C. This flash vessel is a vertical, stainless steel

SS304 vessel with a volume of 2402 liters. The flash vessel has a diameter of 0.914 meters and a tangent-to-tangent height of 3.66 meters. The water in the feed is removed as steam (69) and mixed with the polymerization reactor water vapor decant (53) and PLA recycle evaporator (61) streams using a mixing valve (V-6). The diphenyl ether stream (71) contains 38,990 kg/day of 99.4 wt. % diphenyl ether and is recycled to the fermentation broth liquid extraction column (S-7).

### 7.4.6 Separation and Solvent Recovery




| Equipment List | |
|---|---|
| ***Displayed Text*** | ***Function*** |
| E-28 | Dichloromethane Mixer |
| HX-14 | Total Condenser |
| HX-15 | Partial Reboiler |
| S-15 | Solvent Distillation Column |
| S-8 | PLA Crystallizer |

*Figure 7.10 – Separation and Solvent Recovery Process Flow Diagram*

*Table 7.7 – Separation and Solvent Recovery Process Stream Report*

| Stream ID | 63.00 | 67.00 | 68.00 | 92.00 | 93.00 | 94.00 |
|---|---|---|---|---|---|---|
| Temperature (°C) | 288.00 | 25.85 | 25.85 | 40.15 | 55.16 | 55.16 |
| Pressure (atm) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total Flow | 10,671 | 116,169 | 10,660 | 69,268 | 46,900 | 46,900 |
| Thermodynamics | | | | | | |
| *Enthalpy (J/kg)* | -6,860 | -3,324,070 | 0 | -1,451,890 | -4,559,570 | -4,559,570 |
| *Entropy (cal/g*K)* | 0.00 | -0.88 | 0.00 | -0.50 | -1.14 | -1.14 |
| Composition | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - |
| *CH2Cl2* | - | 0.69 | - | 1.00 | 0.22 | 0.22 |
| *Enzymes* | - | - | - | - | - | - |
| *Diphenyl Ether* | 0.00 | 0.00 | - | - | 0.00 | 0.00 |
| *Ferment. Sugars* | - | - | - | - | - | - |
| *Lactic Acid* | - | - | - | - | - | - |
| *Methanol* | - | 0.31 | - | 0.00 | 0.78 | 0.78 |
| *N2* | - | - | - | - | - | - |
| *Other Solids* | - | - | - | - | - | - |
| *Other Solutes* | - | - | - | - | - | - |
| *Polylactic Acid* | 1.00 | - | 1.00 | - | - | - |
| *Sodium Citrate* | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - |
| *Water* | - | - | - | - | - | - |
| *Xylitol* | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - |

| Stream ID | 95.00 | 96.00 | 97.00 | 98.00 | 100.00 | 104.00 |
|---|---|---|---|---|---|---|
| Temperature (°C) | 40.15 | 40.15 | 40.15 | 55.16 | 40.15 | 24.11 |
| Pressure (atm) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total Flow | 69,268 | 69,268 | 69,268 | 46,900 | 69,268 | 90,671 |
| Thermodynamics | | | | | | |
| *Enthalpy (J/kg)* | -1,451,890 | -1,451,890 | -1,451,890 | -4,559,570 | -1,451,890 | -1,292,420 |
| *Entropy (cal/g*K)* | -0.50 | -0.50 | -0.50 | -1.14 | -0.50 | -0.45 |
| Composition | | | | | | |
| *Ammonium Hydr.* | - | - | - | - | - | - |
| *Ca(OH)2* | - | - | - | - | - | - |
| *CaSO4* | - | - | - | - | - | - |
| *Cellulose Solid* | - | - | - | - | - | - |
| *CH2Cl2* | 1.00 | 1.00 | 1.00 | 0.22 | 1.00 | 0.88 |
| *Enzymes* | - | - | - | - | - | - |
| *Diphenyl Ether* | - | - | - | 0.00 | - | 0.00 |
| *Ferment. Sugars* | - | - | - | - | - | - |
| *Lactic Acid* | - | - | - | - | - | - |
| *Methanol* | 0.00 | 0.00 | 0.00 | 0.78 | 0.00 | - |
| *N2* | - | - | - | - | - | - |
| *Other Solids* | - | - | - | - | - | - |
| *Other Solutes* | - | - | - | - | - | - |
| *Polylactic Acid* | - | - | - | - | - | 0.12 |
| *Sodium Citrate* | - | - | - | - | - | - |
| *Sulfuric Acid* | - | - | - | - | - | - |
| *Water* | - | - | - | - | - | - |
| *Xylitol* | - | - | - | - | - | - |
| *Xylose* | - | - | - | - | - | - |

The stream of PLA exiting the solvent flash vessel (63) is fed to a mixing vessel (E-28) where it is dissolved in 69,268 kg/day of a recycled dichloromethane stream at 40.1C. The recycled stream contains 69,263 kg/day of dichloromethane, 3.62 kg/day of methanol, and trace water and diphenyl ether. Next, the solution enters a stainless steel SS304, 3,269 liter crystallization vessel (S-8). The vessel has a diameter of 1.07 meters and a tangent-to-tangent height of 3.66 meters. 46,900 kg/day of a recycled methanol stream at 60.7°C is added to the crystallization vessel to promote the dissolved PLA to crystallize out of the dichloromethane solution. The recycled methanol stream contains 36,374 kg/day of methanol, 10,512 kg/day of dichloromethane and 14 kg/day of diphenyl ether. The crystals of PLA are collected from the crystallizer and sold -- this process results in 99.9 wt.% pure crystals of 79,270 molecular weight PLA.

The solvent stream from the crystallizer (67) is fed to a tray distillation column so that the dichloromethane and methanol can be separated. The tray distillation column is a stainless steel SS304 vertical, multi-diameter column with 26 sieve trays, a total condenser and a partial reboiler. The solvent mixture is fed to tray 23 where it begins to separate. The methanol is the less volatile of the two components, so it moves towards the bottom of the column while the dichloromethane moves to the top. This distillation results in distillate recoveries of 0.87 and 0.0001 for dichloromethane and methanol, respectively.

# 8.0 Energy Balance and Utility Requirements

### 8.1 Heat Integration Strategy

There is one main heat recycling loop in the process that is intended to use all excess heat generated in the process to heat the input BSG wash water. The main loop uses all of the heated steam generated by evaporators and flash drums to heat the entering water stream. The steam is then condensed to a saturated liquid and recycled as liquid water. In this way, most of the heat from the recycle water and steam is recovered.

Two steam streams are recycled from the process. The first stream (86) is the steam stream leading the xylitol flash evaporator (S-9). The steam leaving the evaporator has a flow rate of 144,105 kg/day and a temperature of 104C. In order to increase the energy potential of the steam, it is passed through a heat exchanger (HX-16) and heated to 151°C by the polymerization reactor (R-6) effluent stream. The resulting hot steam stream (101) is passed through the finished xylitol crystal product (E-10) in order to sterilize any remaining *Candida tropicalis* in the product and continues on to a mixing valve (V-4) where it is combined with the stream exiting the lactic acid evaporator vessel (S-14). This stream (77) contains 34,103 kg/day of water vapor at 110C. After both steam streams are combined, the resulting stream contains 178,208 kg/day of 143°C steam. This steam is first used to heat the inlet water stream from 62°C to 102°C. In this process, it cools from 142°C to 103°C and some of the steam condenses into water. The stream now has a vapor fraction of 0.87 as it passes into another heat exchanger (HX-3). This exchanger is used to heat the entering sulfuric acid solution from 25°C to 100°C. In doing so, the steam stream vapor fraction drops to 0.86. The stream is then passed through a condenser (HX-2) that fully condenses the remaining steam into liquid water. The liquid stream (80) is still at 103°C and is fed to another mixing valve (V-3).

The condensed water stream is combined with the water exit stream (75) from the diphenyl ether and water decanter (S-11) and a municipal water input stream (79) at 25C. The decanter stream contains 5426 kg/day of water at 90C. The municipal water stream contains 200,582 kg/day of water at 25C. When the three streams are combined by mixing value V-3, the resulting stream (78) contains 384,215 kg/day of water at 62C. This water is then fed to HX-4 where it is heated to 102°C and added to the process.

There are other, smaller heat integration loops that recycle heat locally within various parts of the process. One such heat integration loop occurs between the xylitol crystal separator (S-3) and the bottoms product from exiting the xylitol evaporator (S-9). The liquid stream from the crystal separator (25) exits at 5°C with a flow rate of 12,808 kg/day. It passes through a heat exchanger (HX-21) where it cools the 25,010 kg/day evaporator bottoms stream from 103°C to 46C. In the process, the stream heats from 5°C to 95°C. After half of the stream is purged, it is mixed with the sugar stream entering the xylose fermenter (V-12). This mixing heats the entering sugar solution from 25°C to 27°C, which lessens the energy requirement of the fermentation heater (HX-20) and also allows for the leftover xylose in the recycle stream to be fermented.

There are also multiple product-to-feed heat exchanges that take place in the process. One loop uses the wet BSG acid hydrolysis product stream (5) in a plate and frame heat exchanger to heat the wet BSG slurry feed from 76°C to 140°C. In doing so, it cools from 150°C to 103°C. This economizing heat exchanger was calculated to save almost $4,000,000 a year in energy costs, as the incoming wet BSG feed has the highest flow rate of any stream in the process at 516,332 kg/day. Another product-to-feed loop exists around the diphenyl ether flash evaporation vessel in the PLA purification process (S-12). This loop heats the entering PLA in diphenyl ether solution from 110°C to 237°C (HX-11), greatly reducing the utility energy required to further heat the stream to the flash temperature of 288°C (HX-9). In doing so, it cools from 288°C to 180C, which also reduces the energy needed to cool the stream to 157°C for the next separation (S-13).

## 8.2 Process Utilities

*Table 8.1 – Process Utility Summary*

| Utility | Equipment Item | Quantity | Sum of Duty (kW) |
|---|---|---|---|
| **Cooling Water (kg/day)** | | **23,277,893** | **-5,624.3** |
| | R-3 | 8,231,000 | -1,989 |
| | HX-13 | 14,991,000 | -3,622 |
| | E-9 | 55,893 | -13.5 |
| **Electricity (kW)** | | **2,357** | **-1,989.4** |
| | HX-17 | 80.9 | 80.9 |
| | R-1 | 745.5 | -745.5 |
| | S-13 | 27.7 | -27.7 |
| | S-92 | 1,359.5 | -1,359.5 |
| | R-5 | 40.6 | -40.6 |
| | HX-8 | 94.4 | 94.4 |
| | S-11 | 8.6 | 8.6 |
| **High Pressure Steam (kg/day)** | | **41,044** | **816.8** |
| | R-6 | 41,044 | 816.8 |
| **Low Pressure Steam (kg/day)** | | **161,019** | **4,085** |
| | S-10 | 0.35 | ~0 |
| | HX-15 | 9,571 | 242.8 |
| | HX-16 | 1,718.1 | 43.6 |
| | S-9 | 149,730 | 3,798.6 |
| **Medium Pressure Steam (kg/day)** | | **5,567.6** | **131.1** |
| | HX-1 | 5,567.6 | 131.1 |
| **Refrigerant - Freon 12 (kg/day)** | | **803,280** | **-37.2** |
| | HX-7 | 803,280 | -37.2 |
| **Grand Total** | | | **-2,626.6** |

# 9.0 Equipment Lists and Unit Descriptions

### 9.1 Xylitol Fermenter

Xylitol is produced as *Candida tropicalis* reduces xylose through its pentose phosphate pathway. It is a primary metabolite, meaning that *Candida* produces xylitol during its growth phase, instead of just at stationary phase. *Candida's* metabolism, the acidic conditions under which it most efficiently produces xylitol, and lower capital and operational costs all support the choice to run this fermentation continuously.

This strain of *Candida* was chosen because it has a higher yield and specific volumetric production than *Candida guillermondii*, the previously considered organism. It is also unique in having an optimal pH of 2.5 for xylitol production. Since the steps preceding fermentation include an acid wash (pH ~0.37), and neutralization with calcium hydroxide, this low pH saves money by requiring significantly less base to neutralize to optimal conditions. The low pH environment also makes contamination by other microorganisms unlikely. This acidic environment may necessitate that the fermenter be made from a more expensive metal, but this cost is expected to be relatively small in relation to other expenses.

A CFSTR will be used as the fermenter. It will be kept at 32°C and under microaerobic conditions (~3.5% saturation). As only microaerobic conditions are needed, air may be used to add oxygen to the system. The Monod substrate saturation coefficient and maximum growth rate were found for the organism under similar circumstances, and these values were used to calculate $D_{opt}$, the optimal dilution rate (0.084 $h^{-1}$). In order to feed the fermenter at the correct xylose concentration (80g $L^{-1}$), the input stream must be diluted by adding 1380 liters per hour of water. This dilution makes the total incoming stream 4120 L $h^{-1}$. By dividing the flow rate by the dilution rate, the necessary volume of the reactor was calculated at approximately 50,000L. This was taken to be 80% of the maximum fermenter volume to allow for head space. Thus, the total fermenter volume is about 62,000L. The outlet stream will lead to a log6 sterilization treatment and a centrifuge to remove the yeast cells from the broth.

### 9.2 Lactic Acid Fermenter

A specific strain of *Lactobacillus delbrueckii*, UFV H2B20, was found to possess greatly enhanced fermentation performance if its conditions were well-controlled. Specifically, the pH of the broth must be kept at ~6.0. While this consideration increases the cost of the process, it results in the bacteria converting 98% of the glucose it metabolizes into lactic acid, which may make up for the cost when compared to the yield without the control: 82%. One possible base for regulating pH is ammonia from the preceding neutralization step. This can then be separated using the ensuing liquid extraction. Since lactic acid is a primary metabolite, this fermentation lends itself to continuous processing as well. It should be noted, however, that *L. delbrueckii* does not share *C. tropicalis*' acidophilic nature, and so does not incur the benefit of added sterility from the acidic solution.

This fermenter is maintained at a temperature of 37°C. The reactor is sized in the same way as for *C. tropicalis*. The reported specific growth rate for *L. delbrueckii* under these conditions is 0.183 $h^{-1}$. The input stream comes in very much more concentrated than the optimal substrate concentration, so a large amount of water - 6,000L $h^{-1}$ - must be added to the stream to achieve the optimal concentration. This brings the total inlet volume to 7,600L $h^{-1}$, which means that in order to maintain steady state, the reactor must be 76,000L. To account for headspace, the actual fermenter size is taken to be 95,000L.

As *L. delbrueckii* is GRAS, and has a precedent of being used in food-related applications, stringent sterilization steps need not be taken, although thorough filtration will still be important. The lactic acid is released to the supernatant, so they need not be lysed and there is little to no concern over toxins, as they are gram positive. The bacteria is separated out during the liquid extraction step.

**9.3 Heat Exchangers**

All heat exchangers were shell-in-tube with the exception of the acid hydrolysis feed heat exchanger (HX-5). In order to maximize the heat transfer area of the exchanger, it is modelled as a plate heat exchanger. This allowed for all of the BSG feed to be heated using four identical exchangers. Each identical exchanger has a heat transfer area of 1,672 meters squared and a design pressure and temperature of 4 atm and 177.8°C, respectively. Another notable heat exchanger is the inlet water heat exchanger (HX-3), which uses recycle steam to heat the entering municipal water and condensed steam combined stream. This heat exchanger is modelled as a shell-in-tube exchanger with a heat transfer area of 30.91 square meters. The shell material is 321S stainless steel, the tubes are at a pitch of 0.03 with a length of 6.1 meters and an operating temperature of 85°C. The shell contains the hot fluid and operates at a temperature of 145°C.

The cooling heat exchanger for the xylitol crystallization (HX-21) is constructed of 321S stainless steel with a heat transfer area of 3.05 square meters. It consists of 6.1 meter long tubes at a pitch of 0.03 meters and a tube operating temperature of 95°C. The shell has an operating temperature of 103°C. The following exchanger used to cool the xylitol stream further (HX-7) is also constructed of 321S stainless steel. The exchanger has a tube side operating temperature of -24°C and a shell operating temperature of 103°C.

## 9.4 PLA Solvent Distillation Column

The tray distillation column used to separate the PLA solvent mixture (S-15) is constructed out of stainless steel SS304. The column has a diameter of 1.07 meters, a tangent-to-tangent height of 10.97 meters and 12 sieve trays at a tray spacing of 0.61 meters. The design temperature of the column is 121°C and the operating temperature of the column is 63.3°C. The column is designed with a total distillate condenser and a partial reboiler for the bottoms product.

# 10.0 Equipment Cost Summary

The purchased and installed costs for our equipment units were calculated using Aspen Plus, and are summarized in Table 11.1. Our total bare module costs for this process would be $26,937,310. This analysis showed that the most expensive units in the process are the two fermenters, accounting for 33.2% of the total bare module costs. All equipment was modelled as stainless steel units to prevent corrosion by some of the strong acids and bases.

*Table 10.1 – Equipment Cost Summary*

| Equipment | Unit Number | Equipment Cost ($) | Installed Cost ($) | Bare Module Cost ($) |
|---|---|---|---|---|
| **Agitated Reactors** | | | | |
| Xylitol Fermenter | R-2 | 1,163,700 | 386,400 | 1,550,100 |
| L.A. Fermenter | R-5 | 2,829,200 | 571,200 | 3,400,400 |
| Neutrlizing Reactor | R-1 | 98,100 | 172,000 | 270,100 |
| AAS Reactor | R-3 | 408,300 | 241,300 | 649,600 |
| Saccharification Reactor | R-4 | 115,100 | 175,800 | 290,900 |
| Polymerization Reactor | R-6 | 196,900 | 187,100 | 384,000 |
| Acid Hydrolysis Reactor | R-7 | 378,500 | 241,500 | 620,000 |
| **Vertical Vessels** | | | | |
| Water/Ether decanter | S-11 | 27,700 | 143,100 | 170,800 |
| PLA/Ether Flash | S-12 | 27,900 | 157,700 | 185,600 |
| Ether Recovery Flash | S-13 | 27,900 | 145,600 | 173,500 |
| Lactic Acid Dryer | S-14 | 33,600 | 159,300 | 192,900 |
| PLA Recycle Dryer | E-9 | 27,700 | 143,600 | 171,300 |
| Xylitol Crystallizer | E-6 | 27,700 | 145,800 | 173,500 |
| Chromatography Column | S-2 | 31,200 | 134,900 | 166,100 |
| Chromatography Column | S-16 | 31,200 | 134,900 | 166,100 |
| Xylitol Evaporator | S-9 | 32,900 | 158,700 | 191,600 |
| PLA Crystallizer | S-8 | 31,200 | 134,900 | 166,100 |
| **Mixers** | | | | |
| PLA Steam Recovery | V-6 | 27,900 | 145,600 | 173,500 |
| Water Recovery | V-2 | 15,400 | 94,700 | 110,100 |
| **Trayed Towers** | | | | |
| L.A. Extraction Column | S-7 | 435,605 | 295,200 | 730,805 |

| | | | | |
|---|---|---|---|---|
| *PLA Solvent Recover* | S-15 | 236,100 | *160,000* | 396,100 |
| ***Centrifuges*** | | | | |
| *PLA Ferm. Centrifuge* | S-10 | 39,300 | *149,700* | 189,000 |
| *Xylitol Ferm. Centrifuge* | S-4 | 31,200 | *134,900* | 166,100 |
| *Sacc. Centrifuge* | S-6 | 1,533,700 | *366,000* | 1,899,700 |
| *Neutralizer Centrifuge* | S-5 | 219,100 | *52,300* | 271,400 |
| ***Filters*** | | | | |
| *Pretreatment Filter* | S-1 | 240,200 | *114,000* | 354,200 |
| *Xylitol Crystal Filter* | S-3 | 115,900 | *80,600* | 196,500 |
| ***Mixed Tanks*** | | | | |
| *Pretreatment Wash* | E-1 | 93,800 | *131,900* | 225,700 |
| *AAS Wash* | E-8 | 82,700 | *130,200* | 212,900 |
| *Xylitol Wash* | E-10 | 31,700 | *107,800* | 139,500 |
| ***Heat Exchangers*** | | | | |
| *Wet BSG Heater* | HX-1 | 566,000 | *1,851,900* | 2,417,900 |
| *Steam Condenser* | HX-2 | 65,700 | *103,500* | 169,200 |
| *Inlet Water HX* | HX-3 | 8,400 | *46,900* | 55,300 |
| *Inlet Sulfuric Acid HX* | HX-4 | 39,000 | *109,100* | 148,100 |
| *Wet BSG Recycle HX* | HX-5 | 10,800 | *72,900* | 83,700 |
| *L.A.Ferm. HX* | HX-6 | 10,000 | *69,400* | 79,400 |
| *Xylitol Cooling HX* | HX-7 | 10,500 | *87,000* | 97,500 |
| *L.A. Polymerization HX* | HX-8 | 13,500 | *75,200* | 88,700 |
| *PLA Ether Flash HX* | HX-9 | 16,100 | *77,100* | 93,200 |
| *Polymerization Feed HX* | HX-10 | 9,500 | *72,400* | 81,900 |
| *Feed Ether HX* | HX-11 | 15,000 | *74,300* | 89,300 |
| *Xylose Heating HX* | HX-20 | 8,400 | *45,800* | 54,200 |
| *PLA Steam HX* | HX-16 | 19,200 | *88,100* | 107,300 |
| | | | | |
| ***Total*** | | 9,383,505 | *8,170,300* | 17,553,805 |

# 11.0 Economic Analysis

## 11.1 Sensitivity Analysis

A sensitivity analysis was performed to assess the percent changes in ROI caused by a 1%, 5%, and 10% change in both directions of various inputs. The effect on ROI of changes in xylitol price, PLA price, utility cost, and raw materials cost is summarized in Table 11.1.

*Table 11.1. The percent change in ROI due to 1%, 5%, and 10% changes in both directions of various inputs to the process*

| ***% Change in ROI*** | ***+1%*** | ***-1%*** | ***+5%*** | ***-5%*** | ***+10%*** | ***-10%*** |
|---:|---:|---:|---:|---:|---:|---:|
| ***Xylitol Price*** | 0.69% | -0.70% | 3.56% | -3.59% | 6.68% | -7.71% |
| ***PLA Price*** | 1.37% | -1.17% | 5.66% | -6.39% | 10.54% | -13.95% |
| ***Utilities*** | 0.00% | 0.00% | 0.00% | 0.23% | -0.23% | 0.46% |
| ***Raw Materials*** | -0.46% | 0.46% | -2.12% | 2.26% | -4.59% | 4.20% |

The analysis shows that ROI is mostly sensitive to changes in the price of PLA, followed by changes in xylitol price, changes in raw material costs, and finally changes in utility costs. The ROI would be greatly affected by a decrease in the price of PLA, which implies that we must competitively sell this product at its current price for the ROI to remain attractive to investors. Regarding our variable costs, the ROI would be greatly affected at a 10% increase in raw materials cost. However, ROI is not very sensitive to changes in utility costs, so even a 10% increase in this variable cost would not reduce ROI by much.

## 11.2 Profitability Analysis

*Raw Materials*

Following the preliminary analysis described in the product selection section, an in depth assessment of all the raw materials needed to produce each of the selected products was carried out. While the preliminary analysis focused mainly on the cost of the most abundant materials (acids, bases, and buffers), this complete thorough assessment also includes enzymes, catalysts, fermentation media and solvents. Price quotes for yearly bulk orders of these materials were obtained from contacting different chemical manufacturers in the northeast region. In all cases where available, manufacturers were chosen over distributors to avoid higher resale prices. Table 11.2 details the providers and costs of raw materials.

*Table 11.2 Providers and costs of raw materials*

| ***Material*** | **Provider** | **Quantity/ year (kg)** | **Price/ kg** | **Cost/ year** |
|---|---|---|---|---|
| *Nitrogen* | Air Products | 50,000 | $0.21 | $10,500 |
| *Calcium Hydroxide* | Chemetall | 369,745 | $0.20 | $73,949 |
| *Sulfuric Acid* | Hibrett Puratex | 493,115 | $0.13 | $64,105 |
| *Sodium Citrate* | Essential Fine Ingredients Inc | 1,898,365 | $0.80 | $1,518,692 |
| *Ammonium Hydroxide* | Hibrett Puratex | 10,946,350 | $0.30 | $3,283,905 |
| *Cellulase* | Amano Enzyme Inc | 15,671 | $3.00 | $47,013 |
| *YM Medium* | Teknova | 50,000 | $26.00 | $1,300,000 |
| *MRS Medium* | Alpha Biosciences | 228,900 | $36.00 | $8,240,400 |
| | ***Total Cost/Year*** | | | **$14,538,564** |
| *C. tropicalis Cells* | ATCC | 1 inoc. | N/A | $290 |
| *L. delbrueckii Cells* | ATCC | 1 inoc. | N/A | $294 |
| *Methanol* | Hibrett Puratex | 36,158 | $0.50 | $18,079 |
| *Dichloromethane* | Akzo Nobel | 80,000 | $0.41 | $32,400 |
| *Diphenyl Ether* | Crescent Chemical Co | 40,000 | $2.10 | $84,000 |
| *Tin Oxide* | Belmont Metals Inc | 15776.5 | $40.00 | $631,060 |
| | ***Extra Raw Materials Cost*** | | | **$765,539** |

The tin oxide catalyst and the organic solvents (methanol, dichloromethane and diphenyl ether) are not factored into the yearly cost of raw materials since they are purchased once and recycled throughout the process as they are not consumed. These materials, as well as their respective transport costs, are therefore factored into direct permanent investment costs under "Costs of Other Materials".

*Water Costs*

Using the current water usage rate of \$0.00145/kg provided by the Philadelphia Water Department, our yearly input costs would be \$132,784. A total of 91,575,215 kg of freshwater are required for streams 79 (input to HX4) and 33 (input to E8) on the process flow diagram.

Water disposal costs were also estimated using a disposal rate of \$0.00108 provided by the Philadelphia Water Department. The water effluent streams that are not recycled into the process are streams 47 (aqueous waste from S7) and 84 (purge from V5). The total water effluent from our process is 131,308,297 kg/year, which would account for a water discharge cost of \$141,813 per year.

*Transport Costs*

The yearly transport costs of delivering raw materials from providers to the plant and BSG from breweries are summarized in Table 11.3. The Logistics section includes a detailed analysis on the delivery scheduling for BSG, as well as how transport costs were obtained based on type of material, distance, and freight type.

*Table 11.3. Yearly transport costs for all raw materials delivered to the plant*

| Material Type | Cost/year |
|---|---|
| BSG | $65,700 |
| Treatment Chemicals | $41,803 |
| Total | $107,503 |

*Fixed Costs*

The plant will run continuously 24 hours a day, and it is assumed it will be operating fully for 330 days a year. Each day will have 3 shifts, with 22 operators working during each shift. The number operators for each section of the process are as follows:

[4] for solid BSG input to filter process, including H2SO4 reactor
[4] for solid-liquids handling of hemicellulose to xylitol fermenter
[2] for xylitol fermenter
[2] for liquids handling of xylitol purification process
[4] for solid-liquids handling of cellulose to lactic acid fermenter
[2] for lactic acid fermenter
[4] for lactic acid polymerization to PLA process

*Table 11.4. General Information Summary of the Project*

| | |
|---|---|
| **General Information** | |
| Process Title | Bioprocessing with Brewer's Spent Grain |
| Products | Xylitol and Polylactic Acid |
| Plant Site Location | Philadelphia, PA |
| Site Factor | 1 |
| Operating Hours per Year | 8400 |
| Operating Days per Year | 350 |
| Operating Factor | 0.9 |
| | |
| **Product Information** | |
| This process will yield | 3,605,105 kg/year Xylitol |
| | 4,062,476 kg/year PLA |
| Price Xylitol | $10/kg |
| Price PLA | $15/kg |

*Table 11.5. Chronology of the Project*

| Chronology | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **Year** | **Action** | **Distribution of Permanent Investment** | **Production Capacity** | **Depreciation** 5 year MACRS | **Product Prices** |
| 2017 | Construction | 100% | 0.0% | | |
| 2018 | Production | 0% | 45.0% | 20.00% | $10.00/$15.00 |
| 2019 | Production | 0% | 67.5% | 32.00% | $10.00/$15.00 |
| 2020 | Production | 0% | 90% | 19.20% | $10.00/$15.00 |
| 2021 | Production | | 90% | 11.52% | $10.00/$15.00 |
| 2022 | Production | | 90% | 11.52% | $10.00/$15.00 |
| 2023 | Production | | 90% | 5.76% | $10.00/$15.00 |
| 2024 | Production | | 90% | | $10.00/$15.00 |
| 2025 | Production | | 90% | | $10.00/$15.00 |
| 2026 | Production | | 90% | | $10.00/$15.00 |
| 2027 | Production | | 90% | | $10.00/$15.00 |
| 2028 | Production | | 90% | | $10.00/$15.00 |
| 2029 | Production | | 90% | | $10.00/$15.00 |
| 2030 | Production | | 90% | | $10.00/$15.00 |
| 2031 | Production | | 90% | | $10.00/$15.00 |
| 2032 | Production | | 90% | | $10.00/$15.00 |

*Table 11.6 Input Summary*

| | | |
|---|---|---|
| **Fixed Costs** | | |
| **Operations** | | |
| Operators per shift | 22 | (assuming 3 shifts) |
| Direct Wages and Benefits | $40 | /operator hour |
| Direct Salaries and Benefits | 15% | of Direct Wages and Benefits |
| Operating Supplies and Services | 6% | of Direct Wages and Benefits |
| Technical Assistance to Manufacturing | $60,000 | per year, per (operator/shift) |
| Control Lab | $65,000 | per year, per (operator/shift) |
| **Maintenance** | | |
| Wages and Benefits | 4.50% | of Total Depreciable Capital |
| Salaries and Benefits | 25% | of Maintenance Wages and Benefits |
| Materials and Services | 100% | of Maintenance Wages and Benefits |
| Maintenance Overhead | 5% | of Maintenance Wages and Benefits |
| **Operating Overhead** | | |
| General Plant Overhead | 7.10% | of Maintenance and Operations Wages and Benefits |
| Mechanical Department Services | 2.40% | of Maintenance and Operations Wages and Benefits |
| Employee Relations Department | 5.90% | of Maintenance and Operations Wages and Benefits |
| Business Services | 7.40% | of Maintenance and Operations Wages and Benefits |
| **Property Taxes and Insurance** | | |
| Property Taxes and Insurance | 2.00% | of Total Depreciable Capital |
| **Straight Line Depreciation** | | |
| Direct Plant: | 8.00% | of Total Depreciable Capital, less 1.18 times the Allocated Costs for Utility Plants and Related Facilities |
| Allocated Plant: | 6.00% | of 1.18 times the Allocated Costs for Utility Plants and Related Facilities |
| **Other Annual Expenses** | | |
| Rental Fees (Office, Laboratory) | $32,500 | |
| Licensing Fees | $0 | |
| Miscellaneous | $0 | |
| **Depletion Allowance** | | |
| Annual Depletion Allowance | $0 | |

| | | |
|---|---|---|
| **Variable Costs** | | |

| General Expenses | | |
|---|---|---|
| Selling/Transfer Expenses | 3.00% | of Sales |
| Direct Research | 4.80% | of Sales |
| Allocated Research | 0.50% | of Sales |
| Administrative Expense | 2.00% | of Sales |
| Management Incentive Compensation | 1.25% | of Sales |

| Working Capital | | |
|---|---|---|
| Accounts Receivable | 30 | Days |
| Cash Reserves (excluding Raw Materials) | 30 | Days |
| Accounts Payable | 30 | Days |
| PLA & Xylitol Inventory | 4 | Days |
| Raw Materials | 2 | Days |

| Total Permanent Investment | | |
|---|---|---|
| Cost of Site Preparations | 5.00% | of Total Bare Module Costs |
| Cost of Service Facilities | 5.00% | of Total Bare Module Costs |
| Allocated Costs for Utility Plants and related facilities | $0 | |
| Cost of Contingencies and Contractor fees | 18.00% | of Direct Permanent investment |
| Cost of Land | 2.00% | of Total Depreciable Capital |
| Cost of Royalties | $0 | |
| Cost of Plant Start-up | 10.00% | of Total Depreciable Capital |

*Table 11.7. Cost Summary*

| Cost Summary |
|---|
| **Fixed Costs** |

| | |
|---|---|
| **Operations** | |
| Direct Wages and Benefits | $ 5,280,000 |
| Direct Salaries and Benefits | $ 792,000 |
| Operating Supplies and Services | $ 316,800 |
| Technical Assistance to Manufacturing | $ 3,960,000 |
| Control Lab | $ 4,290,000 |
| **Total Operations** | **$ 14,638,800** |
| **Maintenance** | |
| Wages and Benefits | $ 1,573,408.3 |
| Salaries and Benefits | $ 393,352 |
| Materials and Services | $ 1,573,408.3 |
| Maintenance Overhead | $ 78,670.4 |
| **Total Maintenance** | **$ 3,618,839** |
| **Operating Overhead** | |
| General Plant Overhead | $ 570,752 |
| Mechanical Department Services | $ 192,930 |
| Employee Relations Department | $ 474,287 |
| Business Services | $ 594,868 |
| **Total Operating Overhead** | **$ 1,832,837** |
| **Property Taxes and Insurance** | |
| Property Taxes and Insurance | **$ 699,293** |
| **Straight Line Depreciation** | |
| Direct Plant: | **$ 2,797,170** |
| Allocated Plant: | $ 0 |
| **Other Annual Expenses** | |
| Rental Fees (Office, Laboratory Space) | $ 32,500 |
| Licensing Fees | $ 0 |
| Miscellaneous | $ 0 |

| | |
|---|---|
| **Total Other Annual Expenses** | **$ 32,500** |
| **Depletion Allowance** | |
| Annual Depletion Allowance | $ 0.00 |
| **Total Fixed Costs** | **$ 23,619,439** |

| | | |
|---|---|---|
| **Variable Costs** | | |
| **General Expenses** | | |
| Selling/Transfer Expenses | | $ 2,618,681 |
| Direct Research | | $ 4,189,890 |
| Allocated Research | | $ 436,447 |
| Administrative Expense | | $ 1,745,787 |
| Management Incentive Compensation | | $ 1,091,117 |
| **Total General Expenses** | | **$ 10,081,922** |
| **Raw Materials (+Transport)** | $4.22 per kg of Products | $14,646,067 |
| **Byproducts** | $0.00 per kg of Products | $0 |
| **Utilities** | $0.20 per kg of Products | $1,139,030 |
| **Total Variable Costs** | | **$ 25,867,019** |

| | |
|---|---|
| **Total Bare Module Costs** | $ 17,553,800 |
| **Direct Permanent Investment** | |
| Cost of Site Preparations | $ 877,690 |
| Cost of Service Facilities | $ 877,690 |
| Allocated Costs for Utility Plants and related facilities | $ 0.0 |
| Cost of Other Materials | $ 766,206 |
| **Direct Permanent Investment** | $ 20,075,400 |
| **Total Depreciable Capital** | |
| Cost of Contingencies and Contractor fees | $ 3,613,600 |

| | |
|---|---|
| **Total Depreciable Capital** | **$ 23,689,000** |
| **Total Permanent Investment** | |
| Cost of Land | $ 473,780 |
| Cost of Royalties | $ 0.0 |
| Cost of Plant Start-up | $ 2,368,900 |
| **Total Permanent Investment - Unadjusted** | $ 26,531,700 |
| **Site Factor** | 1 |
| **Total Permanent Investment** | **$ 26,531,700** |

| **Working Capital** | 2018 | 2019 | 2020 |
|---|---|---|---|
| Accounts Receivable | $ 3,637,057 | $ 5,455,586 | $ 7,274,114 |
| Cash Reserves (excluding Raw Materials) | $ 727,375 | $ 1,091,063 | $ 1,454,750 |
| Accounts Payable | $ 549,228 | $ 823,841 | $ 1,098,455 |
| PLA & Xylitol Inventory | $ 484,941 | $ 727,411 | $ 969,882 |
| Raw Materials | $ 36,615 | $ 54,923 | $ 73,230 |
| **Total** | **$** 4,336,466 | **$** 6,505,142 | **$** 8,673,521 |
| Present Value at 15% | $ 3,771,096 | $ 4,918,822 | $ 5,702,981 |
| **Total Capital Investment** | | **$ 40,924,600** | |

*Table 11.8. Profitability Summary*

| **Profitability Measures** | |
|---|---|
| **Internal Rate of Return (IRR)** | **28.4%** |
| **Net Present Value (NPV) in 2017** | **$80,584,500** |
| **ROI Analysis (3rd Production Year)** | |
| **Annual Sales** | 87,289,400 |
| **Annual Costs** | (49,486,500) |
| **Depreciation** | (4,548,300) |
| **Income Tax** | (13,301,900) |
| **Net Earnings** | 19,952,700 |
| **Total Capital Investment** | **46,047,100** |
| **ROI** | **43.3%** |

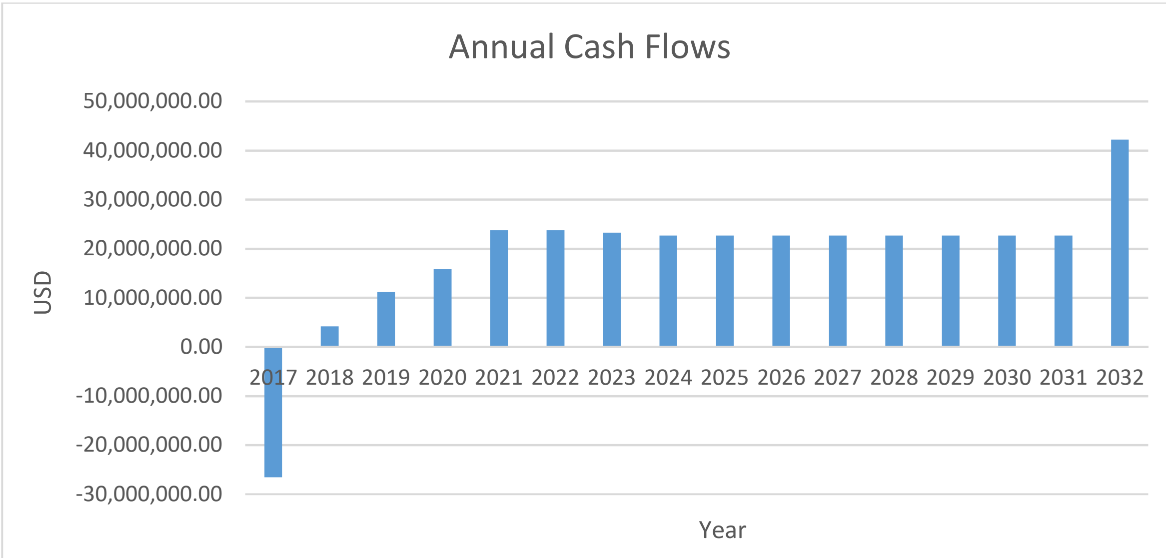



*Figure 11.1. Annual Cash Flows for each year of the plant's lifetime*

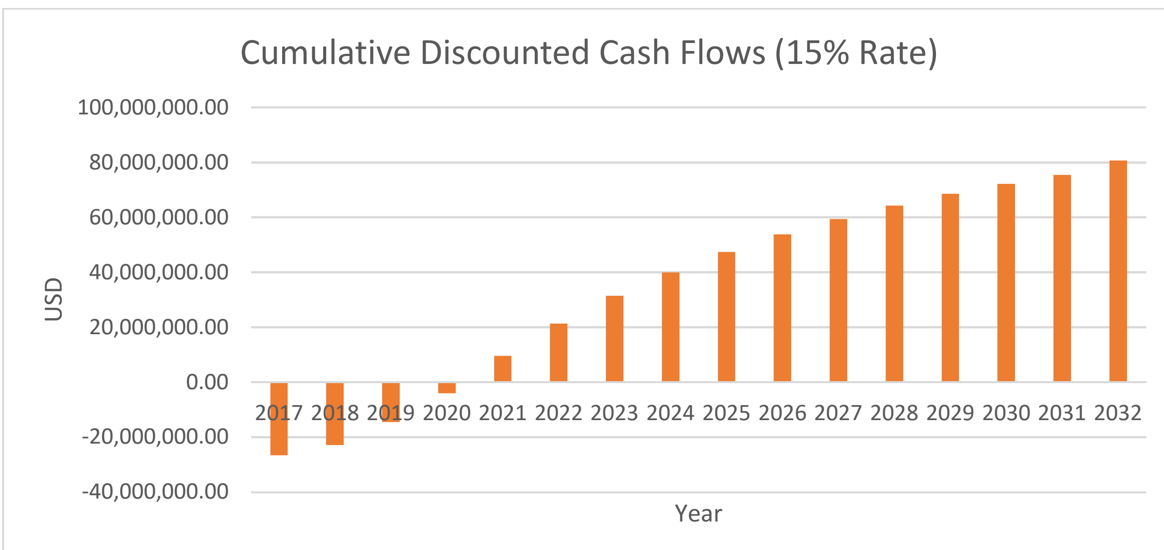



*Figure 11.2. Cumulative Discounted cash flows for each year of the plant's lifetime*

| Cash Flow Summary | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Percentage of Design Capacity | Unit Price of Products | Sales | Capital Costs | Working Capital | Var. Costs | Fix. Costs | Depreciation | Depletion Allowance | Taxable Income | Taxes | Net Earnings | Cash Flow | Cumulative Net Present Value at 15% |
| 2017 | 0% | - | - | (26,531,700) | | | | | - | | | | (26,531,700) | (26,531,700) |
| 2018 | 45% | $10.00/15.00 | 43,644,700 | - | | (20,826,100) | (11,809,700) | (4,737,800) | - | 6,271,100 | 2,508,400 | 3,762,700 | 4,163,700 | (22,911,100) |
| 2019 | 0.68% | $10.00/15.00 | 65,467,000 | - | (4,336,800) | (23,346,600) | (17,714,600) | (7,580,500) | - | 16,825,400 | 6,730,200 | 10,095,300 | 11,170,600 | (14,464,500) |
| 2020 | 90% | $10.00/15.00 | 87,289,400 | - | (6,505,100) | (25,867,000) | (23,619,400) | (4,548,300) | - | 33,254,600 | 13,301,900 | 19,952,800 | 15,827,600 | (4,057,700) |
| 2021 | 90% | $10.00/15.00 | 87,289,400 | - | (8,673,500) | (25,867,000) | (23,619,400) | (2,729,000) | - | 35,074,000 | 14,029,600 | 21,044,400 | 23,773,300 | 9,534,800 |
| 2022 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | (2,729,000) | - | 35,074,000 | 14,029,600 | 21,044,400 | 23,773,800 | 21,354,400 |
| 2023 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | (1,364,500) | - | 36,438,400 | 14,575,400 | 21,863,100 | 23,227,500 | 31,396,300 |
| 2024 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 39,923,200 |
| 2025 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 47,337,900 |
| 2026 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 53,785,500 |
| 2027 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 59,392,000 |
| 2028 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 64,267,300 |
| 2029 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 68,506,700 |
| 2030 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 72,193,100 |
| 2031 | 90% | $10.00/15.00 | 87,289,400 | - | - | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 22,681,800 | 75,398,700 |
| 2032 | 90% | $10.00/15.00 | 87,289,400 | - | 19,515,400 | (25,867,000) | (23,619,400) | - | - | 37,802,900 | 15,121,200 | 22,681,800 | 42,197,200 | 80,584,500 |

*Table 11.9. Cash Flow Summary*

# 12.0 Other Important Considerations

### 12.1 Safety & Good Manufacturing Practices

All personnel will be trained to safely operate equipment around the facility. All materials will be clearly labeled, and will be handled and disposed of according to the safety data sheets. Extra care will be taken with the installation and use of compressed nitrogen gas in cylinders. Personnel will be expected to comply with laboratory and industrial safety measures and report any anomalies observed with the process immediately. Appropriate clothing will be worn at all times and jewelry or other accessories will be removed before entering the plant. Extra care will be taken to avoid microorganism cross-contamination between the two production chains. The plant will contain sanitary facilities and an adequate disposal system. [28]

### 12.2 Logistics

*BSG Collection*

By contacting and surveying multiple breweries in the Philadelphia area, we were able to obtain accurate estimates of how much spent grain would be available for processing on a weekly basis. Our main partner throughout the project has been Dock Street Brewery, which has also provided us with spent grain samples for analysis. Other Microbreweries that expressed interest in our project were Iron Hill, Manayunk, Crime and Punishment, Tired Hands and Philadelphia Brewing Company. Two larger scale breweries, Yards and Flying Fish, have also expressed interest. Based on the numbers these breweries have provided us, we estimated the number of barrels each brewery in the area can offer us yearly according to their size. Realistically there are about 30 microbreweries in the area; however for estimation purposes, very small scale microbreweries such as Crime and Punishment or 2nd Story have been grouped as one small scale microbrewery. These estimates are outlined in Table 12.1.

*Table 12.1 Barrels of spent grain per year available from breweries in the Philadelphia area.*

| Brewery Size | Barrels/year | Number of Breweries | Total Barrels/year |
|---|---|---|---|
| Micro | 6,000 | 10 | 60,000 |
| Medium | 30,000 | 3 | 90,000 |
| Macro | 125,000 | 1 | 125,000 |
| Total | | 14 | 275,000 |

With a total estimate of 275,000 barrels of wet spent grain per year, we would be obtaining around 2.5 million lb/week. By renting heavy duty (80,000lb capacity) trucks, about 32 loads of spent grain will need to be performed to transport wet grain from breweries to our plant. Penske Truck Rental has provided us with rental information and pricing for a Tandem Axle Day Cab 80,000 lb capacity truck. By mapping out the area travelled by the trucks from the breweries to our plant (Figure 12.1), we have estimated that it could take a truck up to 4~5 hours to complete a route circuit, including loading and unloading time. Assuming that each truck can pick up spent grain twice a day (morning and afternoon), only 8 trucks would be needed per day if collection is carried out over the course of two days. The transportation costs incurred are summarized in Table 12.2.

*Table 12.2. Summary of rental cost per week*

| | |
|---|---|
| Number of Loads/week | 32 |
| Loads/Truck | 2 |
| Number of Trucks/day | 8 |
| Collection Days | 2 |
| Truck Rental Price/day | $180 |
| Total Rental Cost/week | $2880 |
| Total Rental Cost/year | $65,700 |

*Transportation of Materials*

Based on the type and quantity of raw materials needed, transportation options from the manufacturers to our plant were considered. Since our process uses mostly common chemicals and a few biological compounds, sourcing materials from nearby states seemed to be the most cost-effective alternative to avoid high shipping costs. Manufacturers of the materials were chosen according to bulk price quotes and location. Freight rates for trucks were more economical than rates for rail transport due to the short distances traveled. The truckload type selected for delivery was 53ft trailers with a 45,000 lb capacity. Table 12.3 details the logistics.

*Table 12.3. Transportation logistics of raw materials*

| **Material** | **Provider** | **Location** | **Quantity/ year (kg)** | **Price/ Truck** | **Number of Trucks** | **Cost/ year** |
|---|---|---|---|---|---|---|
| Nitrogen | Air Products | Allentown, PA | 50,000 | 82 | 3 | $246 |
| Calcium Hydroxide | Chemetall | New Providence, NJ | 369,745 | 70 | 19 | $1,330 |
| Sulfuric Acid | Hibrett Puratex | Pennsauken, NJ | 493,115 | 48 | 25 | $1,200 |
| Sodium Citrate | Essential Fine Ingredients Inc | Port Washington, | 1,898,365 | 84 | 94 | $7,896 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | NY | | | | |
| Ammonium Hydroxide | Hibrett Puratex | Pennsauken, NJ | 10,946,350 | 48 | 537 | $25,776 |
| Cellulase | Amano Enzyme Inc | Elgin, IL | 15,671 | 375 | 1 | $375 |
| YM Medium | Teknova | Hollister, CA | 50,000 | 90 | 3 | $3900 |
| MRS Medium | Alpha Biosciences | Baltimore, MD | 228,900 | 90 | 12 | $1080 |
| Total Cost/Year | | | | | | $41,803 |
| Methanol | Hibrett Puratex | Pennsauken, NJ | 60,000 | 48 | 3 | $144 |
| Dichloromethane | Akzo Nobel | Malvern, PA | 70,000 | 63 | 4 | $252 |
| Diphenyl Ether | Crescent Chemical Co | Islandia, NY | 40,000 | 100 | 2 | $200 |
| Tin Oxide | Belmont Metals Inc | Brooklyn, NY | 15776.5 | 71 | 1 | $71 |
| Extra Raw Materials Transportation Cost | | | | | | $667 |

The transport costs for the tin oxide catalyst and the organic solvents (methanol, dichloromethane and diphenyl ether) are not factored into the yearly transport cost since they are purchased once and recycled throughout the process as they are not consumed. These extra transport costs are therefore factored into fixed costs.

## 12.3 Plant Location & Sizing

*Sizing*

After obtaining the dimensions of our equipment with Aspen Plus, the horizontal surface area occupied by each was calculated and summarized in Table 12.4. If the plant is to be built in only one floor, around 1500 $ft^2$ are needed solely for equipment. To account for piping in between pieces of equipment and to leave enough space for the operator to control the equipment, we would estimate about double the surface area (3000 $ft^2$) for the processing area. However, this can be reduced if the plant is built across two floors, with each product process on its own floor. The largest pieces of equipment, the two fermenters, would be tall enough to occupy both floors so this will be taken into account during construction. By splitting the process into two floors, horizontal surface area needed for the process would be around 1500 $ft^2$. An extra 2000-3000 $ft^2$ will account for storage areas, disposal facilities, and administrative office space.

*Table 12.4. Surface areas of main equipment units.*

| **Equipment Sizing** | | |
|---|---|---|
| | | |
| **Equipment** | **Unit Number** | **Surface Area ($ft^2$)** |
| **Agitated Reactors** | | |
| Xylitol Fermenter | R-2 | 154.3 |
| L.A. Fermenter | R-5 | 207.5 |
| Neutralizing Reactor | R-1 | 4.91 |
| AAS Reactor | R-3 | 44.2 |
| Saccharification Reactor | R-4 | 9.62 |
| Polymerization Reactor | R-6 | 19.6 |
| Acid Hydrolysis Reactor | R-7 | 38.5 |
| **Vertical Vessels** | | |
| Water/Ether decanter | S-11 | 7.07 |

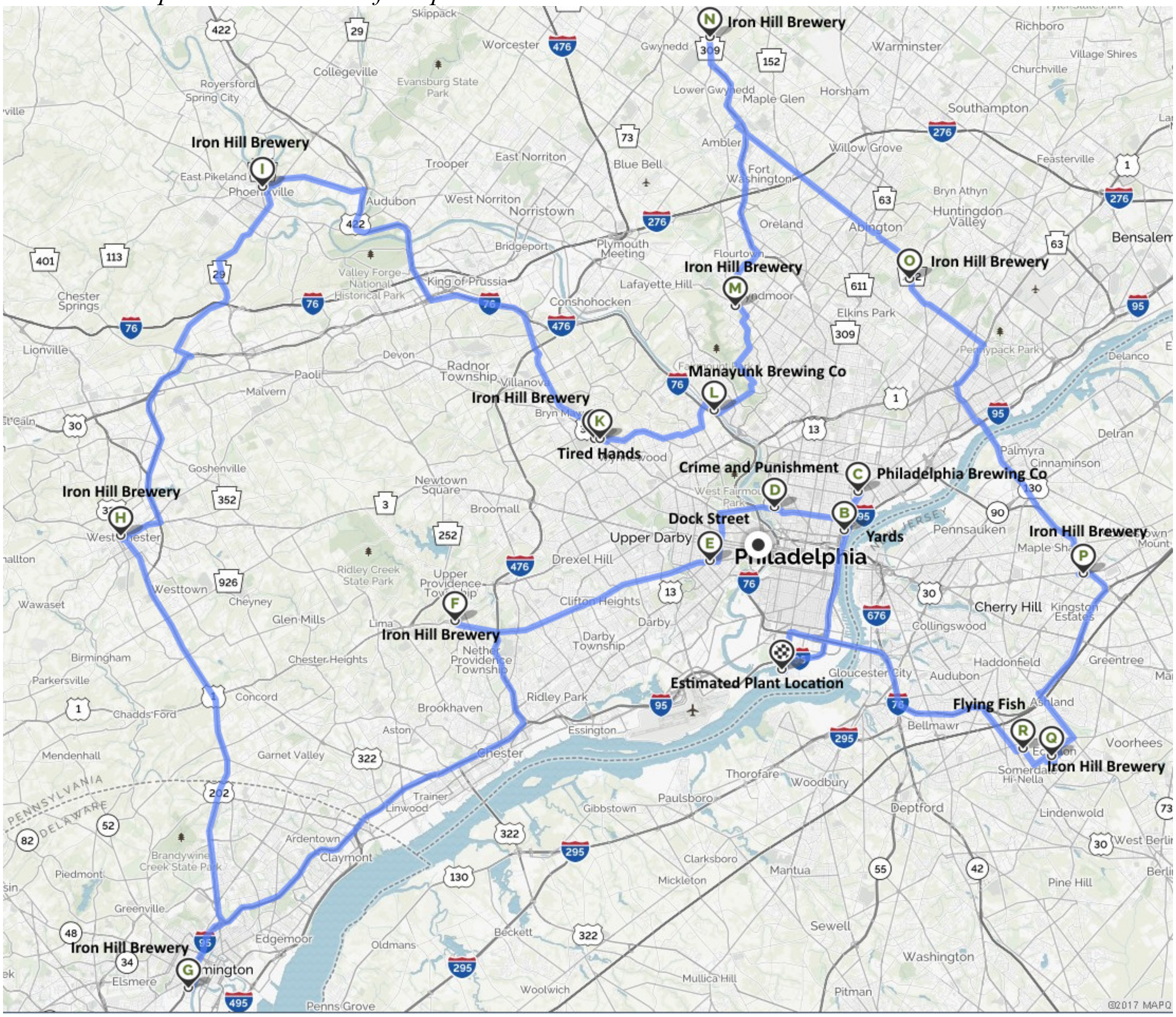
| | | |
|---|---|---|
| PLA/Ether Flash | S-12 | 7.07 |
| Ether Recovery Flash | S-13 | 7.07 |
| Lactic Acid Dryer | S-14 | 12.6 |
| PLA Recycle Dryer | E-9 | 7.07 |
| Xylitol Crystallizer | E-6 | 7.07 |
| Chromatography Column | E-2 | 9.62 |
| Chromatography Column | E-16 | 9.62 |
| Xylitol Evaporator | S-9 | 12.6 |
| PLA Crystallizer | S-8 | 9.62 |
| **Mixers** | | |
| PLA Steam Recovery | V-6 | 7.07 |
| Water Recovery | V-2 | 7.07 |
| **Trayed Towers** | | |
| L.A. Extraction Column | S-7 | 11.6 |
| PLA Solvent Recover | S-15 | 3.14 |
| **Centrifuges** | | |
| PLA Ferm. Centrifuge | S-10 | 15.91 |
| Xylitol Ferm. Centrifuge | S-4 | 9.62 |
| Sacc. Centrifuge | S-6 | 0.55 |
| Neutralizer Centrifuge | S-5 | 0.55 |
| **Filters** | | |
| Pretreatment Filter | S-1 | 21.00 |
| Xylitol Crystal Filter | S-3 | 1.15 |
| **Mixed Tanks** | | |
| Pretreatment Wash | E-1 | 9.62 |
| AAS Wash | E-8 | 7.07 |
| Xylitol Wash | E-10 | 0.79 |
| **Heat Exchangers** | | |
| Wet BSG Heater | HX-1 | 65.62 |
| Steam Condenser | HX-2 | 65.62 |
| Inlet Water HX | HX-3 | 65.62 |
| Inlet Sulfuric Acid HX | HX-4 | 65.62 |
| Wet BSG Recycle HX | HX-5 | 65.62 |

| | | |
|---|---|---|
| L.A.Ferm. HX | HX-6 | 65.62 |
| Xylitol Cooling HX | HX-7 | 65.62 |
| L.A. Polymerization HX | HX-8 | 65.62 |
| PLA Ether Flash HX | HX-9 | 65.62 |
| Polymerization Feed HX | HX-10 | 65.62 |
| Feed Ether HX | HX-11 | 65.62 |
| Xylose Heating HX | HX-20 | 65.62 |
| PLA Steam HX | HX-16 | 65.62 |
| | | |
| **Total** | | 1516.24 |

*Location*

Based on plant sizing, terrain available and the geographic layout of the city, we have determined that a potential location for our plant could be in south Philadelphia, by the Navy Yard area. This location is signaled in Figure 12.1. The Navy Yard area has seen an increasing volume of manufacturing companies and has become a prominent industrial area in Philadelphia. This location would be geographically favorable to reduce transport costs of BSG from the breweries to our plant. Our research yielded a rental price of $6.50/ft$^2$ each year, which would place our yearly rental costs at $32,500 for a 5,000 ft$^2$ plant.

*Figure 12.1. Map of Philadelphia and surrounding areas showing current locations of breweries as well as the potential location of the plant.*



### 12.4 FDA Concerns

Steps need to be taken to ensure good manufacturing practice and address FDA concerns. The use of *Candida tropicalis* may raise FDA concerns if not properly addressed given that *Candida* is the genus of yeast responsible for the most common fungal infections in humans. Recent research conducted in 2016 has reported the involvement of *C. tropicalis* in Crohn's disease [29]. A purified tropiase isolated from *C. tropicalis* has demonstrated hemorrhagic activity and an increase in capillary permeability [30]. Since xylitol is to be used in the food industry, the presence of *Candida* pathogens raises great health concerns.

Due to pathogenicity caused to humans, *C. tropicalis* needs to be thoroughly eliminated from the xylitol product. Sterility assurance level should be $10^{6}$, or one in a million probability of non-sterility. After exploring different techniques on microbial disinfection, steam sterilization seemed to be the most effective to achieve the required sterility assurance level on an industrial scale. Steam inactivates microorganisms by denaturing proteins or causing cell lysis. Steam at 134°C would be sufficient to inactivate the microorganisms after 3-4 minutes of exposure. Fungal inactivation by UV light irradiation also seemed to be a simple, cost-effective disinfection method. A study investigating the inactivation of several *Candida* pathogens grown at 35°C used Philips 20W/C fluorescent lights with an emission spectrum of 250-370 nm and a peak at 254 nm. The results of this study show that *C. tropicalis* was inactivated after 20 minutes of UV exposure [31]. However, while this was successful at laboratory scale, it may be difficult to achieve $10^{6}$ sterilization on an industrial scale.

Our process would need to include steam exposure of the aqueous xylitol fermentation product before the crystallization procedure. The aqueous xylitol and a steam stream could flow through a pipe system with a residence distribution time of 3-4 minutes. Since our process generates a vast quantity of steam, this would be readily available. The short exposure time of 3-4 minutes would not add a bottleneck to the process, and steam is an environmentally friendly disinfection option since no additional substances are produced.

Additionally, all materials used for general pretreatment and xylitol processing will be of food grade quality (U.S.P or A.C.S. grade). Materials used only in the PLA process will be of technical grade quality.

## 12.5 Environmental Concerns

*Gas Emissions*

Our fermenters will release $CO_2$ as a byproduct of fermentation. This greenhouse gas will be treated with $CO_2$ scrubbers before it is released into the atmosphere to ensure that the gas does contain any toxic substances or organisms.

*Wastewater Management*

Throughout our plant, water is an effluent in various processes. Taking safety measures into consideration, these water streams can be recycled into the process to reduce the amount of clean water input. Processes that include water both as an input and an effluent, such as the aqueous ammonia soaking wash step, could reuse part of the effluent stream as an input source to the aqueous ammonia soaking reactor, given that the stream would not contain any extra contaminants. Water recovered as steam through evaporation can also be inputted back into the process as a water heating source. An important consideration when reusing wastewater from the xylitol process is to ensure that *C. tropicalis* is inactive before using the water streams in other parts of the process to prevent pathogenic contamination. This can be accounted for by inactivating the microorganism as soon as the aqueous xylitol exits the fermenter.

Water that is not reused in our process will be treated for solids and cell debris removal before directing it to Philadelphia wastewater treatment plants. Filtration with coarse and fine screens will be used in effluent water streams containing solids or cell debris. Water streams that are free from solids will be directed mainly to the Southwest Water Pollution Control Plant as it is the closest to our plant. The Philadelphia Water Department Industrial Waste Unit issues permits specifying water requirements to regulate water discharges to the sewers and wastewater treatment plants. Following these guidelines, we will need to ensure that water streams are of pH no less than 6 and no higher than 9 before they enter the sewer system. Streams outside this pH range will need further neutralization.

### 12.6 Chemical & Biological Waste Management

*Calcium Sulfate*

The calcium sulfate precipitated out in the xylitol pre-fermentation process should be handled and disposed in a waste disposal container according to local, state, and federal regulations. Calcium sulfate is a recyclable substance that has applications in the construction industry, so the product can be disposed of through collection by a recycling facility.

*Solvents*

Solvents used in the lactic acid polymerization process, such as methanol, diphenyl ether, and dichloromethane, will be recycled and reused in the process. This would be the most cost-effective alternative, given that we would avoid dealing with disposal costs of organic solvents.

*Biological Waste*

Biological waste will include any cell debris recovered after the fermentations. A main concern that needs to be accounted for when disposing of biological waste is the inactivation of any microorganisms before they are placed in a clearly labeled biological waste container [32].

# 13.0 Conclusions and Recommendations

This report suggests that the proposed process be considered for implementation. Operating costs are somewhat high, but not a roadblock to financial success. Cell culture media dominates the operating costs, and this is considering a continuous process, which uses much less media than the equivalent batch mode.

The authors recommend the following courses of action. During research, several genetically modified versions of *Candida tropicalis* engineered by J.H. Kim *et al.* were considered. They boast a range of useful properties like the ability to ferment arabinose (the second most plentiful sugar in BSG hemicellulose) into xylitol, and increased xylose to xylitol efficiency. These organisms could possibly increase production without increasing operating cost. However, the full reports on these organisms could not be obtained within the timeframe of this project, so they had to be excluded from consideration. Further research into their metabolic parameters could be fruitful.

Secondly, if pre-made media is the most prohibitive cost, it may be better to make the necessary media in-house. Cell debris from fermenter effluent can be used as nutrients to grow up the next batch of culture. Further research would have to be done on obtaining the remaining raw ingredients and costing the mixing and storage vessels for such large batches of media. However, it presents a possible cost-reducing option.

Lastly, the sensitivity analysis revealed that PLA price has the most significant impact on ROI. If the price were to increase by 10%, we would see a large increase in value for the process. The authors recommend researching the viability of such a process in other cities around the country.

# 14.0 Acknowledgements

We would like to thank Dr. Bruce Vrana, Dr. Warren Seider and Dr. Len Fabiano for all of the help and guidance that they provided us while we worked through this project. We would also like to thank Dr. Scott Diamond for submitting this project concept and for working with us to make sure that we were approaching the project in an efficient and intelligent manner. We would like to thank all of the industrial consultants that gave us valuable critique and insightful ideas as we moved through the concept, design, and execution phases of the project and dedicated their time towards helping our group. We are grateful for everyone who offered us their help in completing this project and could not have done it without their guidance.

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# 16.0 Appendices

## Appendix A1 –Equipment Specification Sheets

# FLASH DRYER

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *PLA Recycle Drier* | | Date: *7 April 2017* | | |
| | Item No. E-9 | | | | |
| | No. Required 1 | | By: Group 7 | | |
| **Function:** | Removes water from the stream of wet cellulose solids sent to AAS reactor | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Mixed Feed* | *Water Out* | *Dry PLA Rec.* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | 52808.1 | 51772.3 | 1035.82 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | 0.756717 | 0.771175 | 0.034118 | | |
| *Ferment. Sugars* | 0.00263459 | 0.0026873 | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | 0.201864 | 0.205903 | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.0387842 | 0.0202354 | 0.965882 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 110 | 99.8609 | 99.8609 | | |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material | SS304 | | |
| Diameter | 0.9144 meters | Design Temp | 137.7779517 |
| Height | 3.6576 meters | Operating Temp | 110.0001739 |
| Volume | 2401.932948 liters | | |

| | | | |
|---|---|---|---|
| **Utilities (kW)** | | -13.51 | |
| **Bare Module Cost:** | $ 27,700.00 | **Equipment Weight (lbs)** | 1,900.00 |
| **Installation Cost:** | $ 171,300.00 | **Installed Weight (lbs)** | 13,140.00 |

**Comments and Drawings:**

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Wet BSG Heater* | | Date: *7 April 2017* |
| | Item No. HX-1 | | |
| | No. Required 1 | | By: Group 7 |
| **Function:** | Heats the input wet BSG stream to 150C for the acid hydrolysis reactor | | |
| **Operation:** | | | |

| **Materials Handled:** | *Material In* | *Material Out* |
|---|---|---|
| Quantitiy (kg/day): | 516,332.00 | 516,332.00 |
| Composition: | | |
| *Ammonium Hydr.* | - | - |
| *$Ca(OH)_2$* | - | - |
| *$CaSO_4$* | - | - |
| *Cellulose Solid* | 0.12 | 0.12 |
| *$CH_2Cl_2$* | - | - |
| *Enzymes* | - | - |
| *Diphenyl Ether* | - | - |
| *Ferment. Sugars* | 0.00 | 0.00 |
| *Lactic Acid* | - | - |
| *Methanol* | - | - |
| *$N_2$* | - | - |
| *Other Solids* | - | - |
| *Other Solutes* | - | - |
| *Polylactic Acid* | - | - |
| *Sodium Citrate* | - | - |
| *Sulfuric Acid* | - | - |
| *Water* | 0.88 | 0.88 |
| *Xylitol* | - | - |
| *Xylose* | - | - |
| Temperature (°C): | 140.00 | 150.00 |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 2.58 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 202.78 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 175.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 177.78 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 150.00 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | 131.12 | |
| **Bare Module Cost:** | $ | 10,300.00 | **Equipment Weight (lbs)** | 560.00 |
| **Installation Cost:** | $ | 83,200.00 | **Installed Weight (lbs)** | 7,028.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Steam Condenser* | | |
| | Item No. HX-2 | Date: *7 April 2017* | |
| | No. Required 1 | | |
| | | By: Group 7 | |
| **Function:** | Condenses the recycled steam stream so that it can be reused as feed water | | |
| **Operation:** | | | |
| **Materials Handled:** | *Material In* | *Material Out* | |
| Quantitiy (kg/day): | 152,716.00 | 152,717.00 | |
| Composition: | | | |
| *Ammonium Hydr.* | - | - | |
| *$Ca(OH)_2$* | - | - | |
| *$CaSO_4$* | - | - | |
| *Cellulose Solid* | - | - | |
| *$CH_2Cl_2$* | - | - | |
| *Enzymes* | - | - | |
| *Diphenyl Ether* | - | - | |
| *Ferment. Sugars* | - | - | |
| *Lactic Acid* | - | - | |
| *Methanol* | - | - | |
| *$N_2$* | - | - | |
| *Other Solids* | 0.00 | 0.00 | |
| *Other Solutes* | - | - | |
| *Polylactic Acid* | - | - | |
| *Sodium Citrate* | - | - | |
| *Sulfuric Acid* | - | - | |
| *Water* | 1.00 | 1.00 | |
| *Xylitol* | - | - | |
| *Xylose* | - | - | |
| Temperature (°C): | 102.46 | 102.44 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 67.80 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 130.24 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 25.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 130.24 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 102.46 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | -3622.00 | |
| **Bare Module Cost:** | $ | 53,700.00 | **Equipment Weight (lbs)** | 5,700.00 |
| **Installation Cost:** | $ | 156,900.00 | **Installed Weight (lbs)** | 13,432.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** | *Inlet Water HX* | Date: *7 April 2017* |
| | Item No. | HX-3 | |
| | No. Required | 1 | By: Group 7 |

**Function:** Heats the inlet water to the process using recycled steam

**Operation:**

| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 355,802.00 | 355,802.00 | 152,716.00 | 152,716.00 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | - | - | - | - | |
| *Ferment. Sugars* | - | - | - | - | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | 0.00 | 0.00 | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 1.00 | 1.00 | 1.00 | 1.00 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 58.83 | 95.00 | 145.12 | 102.46 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 30.91 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 172.90 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 95.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 172.90 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 145.12 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 30,900.00 | **Equipment Weight (lbs)** | 3,000.00 |
| **Installation Cost:** | $ | 118,600.00 | **Installed Weight (lbs)** | 10,886.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** | *Inlet Sulf. Acid HX* | | | |
| | Item No. | HX-4 | Date: *7 April 2017* | | |
| | No. Required | 1 | | | |
| | | | By: Group 7 | | |
| **Function:** | Heats the inlet sulfuric acid solution using recycled steam | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
| Quantitiy (kg/day): | 355,802.00 | 355,802.00 | 152,716.00 | 152,716.00 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | - | - | - | - | |
| *Ferment. Sugars* | - | - | - | - | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | 0.00 | 0.00 | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 1.00 | 1.00 | 1.00 | 1.00 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 58.83 | 95.00 | 145.12 | 102.46 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 30.91 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 172.90 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 95.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 172.90 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 145.12 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 30,900.00 | **Equipment Weight (lbs)** | 3,000.00 |
| **Installation Cost:** | $ | 118,600.00 | **Installed Weight (lbs)** | 10,886.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Wet BSG Rec. HX* | | Date: *7 April 2017* |
| | Item No. HX-5 | | |
| | No. Required 4 | | By: Group 7 |
| **Function:** | Product-to-feed heat exchanger to recycle heat from acid hydrolysis exit stream | | |
| **Operation:** | | | |

| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 2,351.00 | 2,351.00 | 152,716.00 | 152,716.00 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | - | - | - | - | |
| *Ferment. Sugars* | - | - | - | - | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | 0.00 | 0.00 | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | 0.57 | 0.57 | - | - | |
| *Water* | 0.43 | 0.43 | 1.00 | 1.00 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 25.00 | 92.00 | 102.46 | 102.46 | |

**Design Data:**

| | | | |
|---|---|---|---|
| Heat Transfer Area | 1,672.25 square meters | Plate Material | 321S |
| No. Identical Units | 4.00 | Design P | 4.16 barg |
| | | Design T | 177.78 C |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | No Utilities | | |
| **Bare Module Cost:** | $ 566,000.00 | | **Equipment Weight (lbs)** | 169,600.00 |
| **Installation Cost:** | $ 2,417,900.00 | | **Installed Weight (lbs)** | 561,026.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Lactic Acid Ferm. HX* | | Date: *7 April 2017* |
| | Item No. HX-6 | | |
| | No. Required 1 | | By: Group 7 |
| **Function:** | Heat the fermentable sugar stream to 37C for the lactc acid fermentation | | |
| **Operation:** | | | |

| **Materials Handled:** | *Material In* | *Material Out* |
|---|---|---|
| Quantitiy (kg/day): | 368,323.00 | 368,323.00 |
| Composition: | | |
| *Ammonium Hydr.* | - | - |
| *$Ca(OH)_2$* | - | - |
| *$CaSO_4$* | - | - |
| *Cellulose Solid* | - | - |
| *$CH_2Cl_2$* | - | - |
| *Enzymes* | - | - |
| *Diphenyl Ether* | - | - |
| *Ferment. Sugars* | 0.04 | 0.04 |
| *Lactic Acid* | - | - |
| *Methanol* | - | - |
| *$N_2$* | - | - |
| *Other Solids* | - | - |
| *Other Solutes* | - | - |
| *Polylactic Acid* | - | - |
| *Sodium Citrate* | - | - |
| *Sulfuric Acid* | - | - |
| *Water* | 0.96 | 0.96 |
| *Xylitol* | - | - |
| *Xylose* | - | - |
| Temperature (°C): | 25.00 | 37.00 |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 2.44 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 152.78 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 125.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 121.11 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 37.00 C | No. Shell Pass | 1.00 | |

| | |
|---|---|
| **Utilities (kW)** | 242.81 |
| **Bare Module Cost:** | |
| **Installation Cost:** | |
| **Comments:** | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Xylitol Cooling HX* | | Date: *7 April 2017* |
| | Item No. HX-7 | | |
| | No. Required 1 | | By: Group 7 |
| **Function:** | Cools the xylitol stream further so that the xylitol crystallizes out. | | |
| **Operation:** | | | |

| **Materials Handled:** | *Material In* | *Material Out* |
|---|---|---|
| Quantitiy (kg/day): | 25,010.30 | 25,010.30 |
| Composition: | | |
| *Ammonium Hydr.* | - | - |
| *$Ca(OH)_2$* | - | - |
| *$CaSO_4$* | - | - |
| *Cellulose Solid* | - | - |
| *$CH_2Cl_2$* | - | - |
| *Enzymes* | 0.46 | 0.46 |
| *Diphenyl Ether* | - | - |
| *Ferment. Sugars* | - | - |
| *Lactic Acid* | - | - |
| *Methanol* | - | - |
| *$N_2$* | - | - |
| *Other Solids* | - | - |
| *Other Solutes* | - | - |
| *Polylactic Acid* | - | - |
| *Sodium Citrate* | - | - |
| *Sulfuric Acid* | - | - |
| *Water* | 0.47 | 0.47 |
| *Xylitol* | 0.46 | 0.46 |
| *Xylose* | 0.07 | 0.07 |
| Temperature (°C): | 103.30 | 5.00 |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 6.42 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 131.08 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | -24.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 131.08 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 103.30 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | -37.19 | |
| **Bare Module Cost:** | $ | 13,800.00 | **Equipment Weight (lbs)** | 1,100.00 |
| **Installation Cost:** | $ | 91,000.00 | **Installed Weight (lbs)** | 6,985.00 |
| **Comments and Drawings:** | | | | |

# HEAT EXCHANGER

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** | *Xylitol Cool HX* | | | |
| | Item No. | HX-21 | Date: *7 April 2017* | | |
| | No. Required | 1 | | | |
| | | | By: Group 7 | | |
| **Function:** | Uses the recycled xylitol liquor to cool the entering xylitol stream | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
| Quantitiy (kg/day): | 12,808.00 | 12,808.00 | 25,010.30 | 25,010.30 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | 0.14 | 0.14 | 0.46 | 0.46 | |
| *Diphenyl Ether* | - | - | - | - | |
| *Ferment. Sugars* | - | - | - | - | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | - | - | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 0.73 | 0.73 | 0.47 | 0.47 | |
| *Xylitol* | 0.14 | 0.14 | 0.46 | 0.46 | |
| *Xylose* | 0.14 | 0.14 | 0.07 | 0.07 | |
| Temperature (°C): | 5.00 | 95.00 | 103.30 | 45.92 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 3.05 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 131.08 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 95.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 131.08 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 103.30 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | No Utilities | | |
| **Bare Module Cost:** | $ 8,600.00 | **Equipment Weight (lbs)** | 590.00 | |
| **Installation Cost:** | $ 62,500.00 | **Installed Weight (lbs)** | 7,690.00 | |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Lactic Poly. Reac. HX* | | |
| | Item No. HX-8 | Date: *7 April 2017* | |
| | No. Required 1 | | |
| | | By: Group 7 | |
| **Function:** | Heats the lactic acid stream to 170C for introduction to the PLA reactor | | |
| **Operation:** | | | |

| **Materials Handled:** | *Material In* | *Material Out* |
|---|---|---|
| Quantitiy (kg/day): | 53,847.70 | 53,847.70 |
| Composition: | | |
| *Ammonium Hydr.* | - | - |
| *$Ca(OH)_2$* | - | - |
| *$CaSO_4$* | - | - |
| *Cellulose Solid* | - | - |
| *$CH_2Cl_2$* | - | - |
| *Enzymes* | - | - |
| *Diphenyl Ether* | 0.74 | 0.74 |
| *Ferment. Sugars* | 0.00 | 0.00 |
| *Lactic Acid* | 0.25 | 0.25 |
| *Methanol* | - | - |
| *$N_2$* | - | - |
| *Other Solids* | - | - |
| *Other Solutes* | - | - |
| *Polylactic Acid* | - | - |
| *Sodium Citrate* | - | - |
| *Sulfuric Acid* | - | - |
| *Water* | 0.01 | 0.01 |
| *Xylitol* | - | - |
| *Xylose* | - | - |
| Temperature (°C): | 93.20 | 170.00 |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 18.57 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 202.78 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 175.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 197.78 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 170.00 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | 94.42 | |
| **Bare Module Cost:** | $ | 22,800.00 | **Equipment Weight (lbs)** | 2,100.00 |
| **Installation Cost:** | $ | 112,200.00 | **Installed Weight (lbs)** | 11,091.00 |

**Comments and Drawings:**

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *PLA Ether Flash HX* | | Date: *7 April 2017* |
| | Item No. HX-9 | | |
| | No. Required 1 | | By: Group 7 |
| **Function:** | Heats the diphenyl ether and PLA mixture in order to flash off the ether | | |
| **Operation:** | | | |

| **Materials Handled:** | *Material In* | *Material Out* |
|---|---|---|
| Quantitiy (kg/day): | 52,808.10 | 52,808.10 |
| Composition: | | |
| *Ammonium Hydr.* | - | - |
| *$Ca(OH)_2$* | - | - |
| *$CaSO_4$* | - | - |
| *Cellulose Solid* | - | - |
| *$CH_2Cl_2$* | - | - |
| *Enzymes* | - | - |
| *Diphenyl Ether* | 0.76 | 0.76 |
| *Ferment. Sugars* | 0.00 | 0.00 |
| *Lactic Acid* | - | - |
| *Methanol* | - | - |
| *$N_2$* | - | - |
| *Other Solids* | - | - |
| *Other Solutes* | - | - |
| *Polylactic Acid* | 0.20 | 0.20 |
| *Sodium Citrate* | - | - |
| *Sulfuric Acid* | - | - |
| *Water* | 0.04 | 0.04 |
| *Xylitol* | - | - |
| *Xylose* | - | - |
| Temperature (°C): | 237.48 | 288.00 |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 4.72 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 400.00 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 350.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 315.78 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 288.00 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | 80.89 | | |
| **Bare Module Cost:** | $ | 12,900.00 | **Equipment Weight (lbs)** | 1,000.00 |
| **Installation Cost:** | $ | 89,800.00 | **Installed Weight (lbs)** | 8,996.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Polymer. Feed HX* | | Date: *7 April 2017* | | |
| | Item No. HX-10 | | | | |
| | No. Required 1 | | | | |
| | | | By: Group 7 | | |
| **Function:** | Uses the steam generated in the PLA process to heat the lactic acid reactor feed | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
| Quantitiy (kg/day): | 53847.7 | 53847.7 | 3775.64 | 3775.64 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | 0.742835 | 0.742835 | 0.262429 | 0.262429 | |
| *Ferment. Sugars* | 0.00258372 | 0.00258372 | - | - | |
| *Lactic Acid* | 0.247453 | 0.247453 | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | - | - | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 0.00712846 | 0.00712846 | 0.737564 | 0.737564 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 22.0031 | 93.2006 | 140.837 | 90 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 1.58451301 square meters | Shell Material | 0 | |
| Number of Shells | 0 | Tube Material | 321S | |
| Tube Design Temp. | 168.6173839 C | Tube Length | 6.096 | meters |
| Tube Op.Temp. | 140.8396061 C | Tube Pitch | 0.03175 | |
| Shell Design Temp | 121.1111111 C | No. Tube Pass | 1 | |
| Shell Op. Temp | 93.19806222 C | No. Shell Pass | 1 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 9,500.00 | **Equipment Weight (lbs)** | 490.00 |
| **Installation Cost:** | $ | 81,800.00 | **Installed Weight (lbs)** | 6,605.00 |
| **Comments and Drawings:** | | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Feed Ether HX* | | |
| | Item No. HX-11 | Date: *7 April 2017* | |
| | No. Required 1 | | |
| | | By: Group 7 | |
| **Function:** | Distillate-to-feed exchanger that heats ether and PLA feed for ether flash | | |
| **Operation:** | | | |

| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 52808.1 | 52808.1 | 42137.1 | 42137.1 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | 0.756717 | 0.756717 | 0.948094 | 0.948094 | |
| *Ferment. Sugars* | 0.00263459 | 0.00263459 | 0.00329987 | 0.00329987 | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | - | - | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | 0.201864 | 0.201864 | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 0.0387842 | 0.0387842 | 0.0486057 | 0.0486057 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 110 | 237.482 | 288 | 180 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 8.631770001 square meters | Shell Material | 0 | |
| Number of Shells | 0 | Tube Material | 321S | |
| Tube Design Temp. | 315.7777778 C | Tube Length | 6.096 | meters |
| Tube Op.Temp. | 288 C | Tube Pitch | 0.03175 | |
| Shell Design Temp | 265.2563217 C | No. Tube Pass | 1 | |
| Shell Op. Temp | 237.4785439 C | No. Shell Pass | 1 | |

| | | | |
|---|---|---|---|
| **Utilities (kW)** | | No Utilities | |
| **Bare Module Cost:** | $ 16,100.00 | **Equipment Weight (lbs)** | 1,300.00 |
| **Installation Cost:** | $ 91,400.00 | **Installed Weight (lbs)** | 8,803.00 |
| **Comments:** | | | |

# HEAT EXCHANGER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Xylose Heating HX* | | Date: *7 April 2017* |
| | Item No. HX-20 | | |
| | No. Required 1 | | By: Group 7 |
| **Function:** | Heats the xylose sugar solution to 32C for the xylitol fermentation | | |
| **Operation:** | | | |

| **Materials Handled:** | *Material In* | *Material Out* |
|---|---|---|
| Quantitiy (kg/day): | 168,700.00 | 175,104.00 |
| Composition: | | |
| *Ammonium Hydr.* | - | - |
| *$Ca(OH)_2$* | - | - |
| *$CaSO_4$* | - | - |
| *Cellulose Solid* | - | - |
| *$CH_2Cl_2$* | - | - |
| *Enzymes* | - | 0.00 |
| *Diphenyl Ether* | - | - |
| *Ferment. Sugars* | 0.00 | 0.00 |
| *Lactic Acid* | - | - |
| *Methanol* | - | - |
| *$N_2$* | - | - |
| *Other Solids* | - | - |
| *Other Solutes* | 0.18 | 0.17 |
| *Polylactic Acid* | - | - |
| *Sodium Citrate* | - | - |
| *Sulfuric Acid* | - | - |
| *Water* | 0.75 | 0.75 |
| *Xylitol* | - | 0.00 |
| *Xylose* | 0.08 | 0.08 |
| Temperature (°C): | 25.00 | 32.00 |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 0.43 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 152.78 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 125.00 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 121.11 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 32.00 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | 43.59 | | |
| **Bare Module Cost:** | $ 8,400.00 | | **Equipment Weight (lbs)** | 270.00 |
| **Installation Cost:** | $ 54,100.00 | | **Installed Weight (lbs)** | 3,337.00 |
| **Comments:** | | | | |

# HEAT EXCHANGER

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *PLA Steam HX* | | Date: *7 April 2017* | | |
| | Item No. HX-16 | | | | |
| | No. Required 1 | | By: Group 7 | | |
| **Function:** | Uses the PLA reactor effluent to heat steam produced in the xylitol process | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Cold In* | *Cold Out* | *Hot In* | *Hot Out* | *Stream 3* |
| Quantitiy (kg/day): | 118,953.00 | 118,953.00 | 105,620.00 | 105,620.00 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | - | - | 0.76 | 0.76 | |
| *Ferment. Sugars* | - | - | 0.00 | 0.00 | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | - | - | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | 0.20 | 0.20 | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 1.00 | 1.00 | 0.04 | 0.04 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 103.30 | 155.20 | 170.00 | 110.00 | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Heat Transfer Area | 15.76 square meters | Shell Material | 321S | |
| Number of Shells | 0.00 | Tube Material | 321S | |
| Tube Design Temp. | 197.78 C | Tube Length | 6.10 | meters |
| Tube Op.Temp. | 155.20 C | Tube Pitch | 0.03 | |
| Shell Design Temp | 197.78 C | No. Tube Pass | 1.00 | |
| Shell Op. Temp | 170.00 C | No. Shell Pass | 1.00 | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 19,400.00 | **Equipment Weight (lbs)** | 1,600.00 |
| **Installation Cost:** | $ | 107,500.00 | **Installed Weight (lbs)** | 9,957.00 |
| **Comments:** | | | | |

# SCRUBBING COLUMN

| | | |
|---|---|---|
| **Identification:** | **Item:** *Fermenter Scrub. Col.*<br>Item No. S-22<br>No. Required 1 | Date: *7 April 2017*<br><br>By: Group 7 |
| **Function:** | Uses feed water to scrub CO2 and cell debris out of fermenter gas | |
| **Operation:** | Z | |

| **Materials Handled:** | *Water Feed* | *Ferm. Gas In* | *Water Out* | *Gas Out* |
|---|---|---|---|---|
| Quantitiy (kg/day): | 355871 | ~100 | ~384216 | ~99 |
| Composition: | | Mostly carbon dioxide and potentially cell debris | Water with trace dissolved carbon dioxide and cell debris. | Scrubbed exit gas. |
| *Ammonium Hydr.* | - | | | |
| *$Ca(OH)_2$* | - | | | |
| *$CaSO_4$* | - | | | |
| *Cellulose Solid* | - | | | |
| *$CH_2Cl_2$* | - | | | |
| *Enzymes* | - | | | |
| *Diphenyl Ether* | - | | | |
| *Ferment. Sugars* | - | | | |
| *Lactic Acid* | - | | | |
| *Methanol* | - | | | |
| *$N_2$* | - | | | |
| *Other Solids* | 0.000196296 | | | |
| *Other Solutes* | - | | | |
| *Polylactic Acid* | - | | | |
| *Sodium Citrate* | - | | | |
| *Sulfuric Acid* | - | | | |
| *Water* | 0.999802 | | | |
| *Xylitol* | - | | | |
| *Xylose* | - | | | |
| Temperature (°C): | 58.831 | 36 | 58.831 | 36 |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material 0 | | | |
| Diameter 0.9144 | meters | Design Temp | 121.1111111 |
| Height 3.6576 | meters | Operating Temp | 58.83099778 |
| Volume 2401.932948 | liters | | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | No Utilities | | |
| **Bare Module Cost:** | $ 15,400.00 | **Equipment Weight (lbs)** | 2,600.00 | |
| **Installation Cost:** | $ 110,100.00 | **Installed Weight (lbs)** | 11,524.00 | |
| **Comments:** | | | | |

# ROTARY DRUM FILTER

| | | | | |
|---|---|---|---|---|
| **Identification:** | **Item:** | *Xylitol Crystal Filter* | | Date: *7 April 2017* |
| | Item No. | S-3 | | |
| | No. Required | 1 | | By: Group 7 |
| **Function:** | Separates the precipitated xylitol crystals from carrier solution | | | |
| **Operation:** | | | | |

| **Materials Handled:** | *Feed* | *Liquid Stream* | *Solid Stream* |
|---|---|---|---|
| Quantitiy (kg/day): | 25010.3 | 12808 | 12202.5 |
| Composition: | | | |
| *Ammonium Hydr.* | - | - | - |
| *$Ca(OH)_2$* | - | - | - |
| *$CaSO_4$* | - | - | - |
| *Cellulose Solid* | - | - | - |
| *$CH_2Cl_2$* | - | - | - |
| *Enzymes* | 0.464588 | 0.136083 | 0.809385 |
| *Diphenyl Ether* | - | - | - |
| *Ferment. Sugars* | - | - | - |
| *Lactic Acid* | - | - | - |
| *Methanol* | - | - | - |
| *$N_2$* | - | - | - |
| *Other Solids* | - | - | - |
| *Other Solutes* | - | - | - |
| *Polylactic Acid* | - | - | - |
| *Sodium Citrate* | - | - | - |
| *Sulfuric Acid* | - | - | - |
| *Water* | 0.465008 | 0.726436 | 0.190615 |
| *Xylitol* | 0.464588 | 0.136083 | 0.809385 |
| *Xylose* | 0.0704042 | 0.137481 | - |
| Temperature (°C): | 5 | 5 | 5 |

**Design Data:**

| | | |
|---|---|---|
| Material | 0 | |
| Application | 0 | |
| Solid Flow | 12202.5 | kg/day |
| Liquid Flow | 12808 | kg/day |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 78,800.00 | **Equipment Weight (lbs)** | - |
| **Installation Cost:** | $ | 86,300.00 | **Installed Weight (lbs)** | 1,348.00 |
| **Comments:** | | | | |

# ROTARY DRUM FILTER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Xylitol Crystal Filter* | | Date: *7 April 2017* |
| | Item No. S-3 | | |
| | No. Required 1 | | |
| | | | By: Group 7 |
| **Function:** | Separates the precipitated xylitol crystals from carrier solution | | |
| **Operation:** | | | |

| **Materials Handled:** | *Feed* | *Liquid Stream* | *Solid Stream* |
|---|---|---|---|
| Quantitiy (kg/day): | 25010.3 | 12808 | 12202.5 |
| Composition: | | | |
| *Ammonium Hydr.* | - | - | - |
| *$Ca(OH)_2$* | - | - | - |
| *$CaSO_4$* | - | - | - |
| *Cellulose Solid* | - | - | - |
| *$CH_2Cl_2$* | - | - | - |
| *Enzymes* | 0.464588 | 0.136083 | 0.809385 |
| *Diphenyl Ether* | - | - | - |
| *Ferment. Sugars* | - | - | - |
| *Lactic Acid* | - | - | - |
| *Methanol* | - | - | - |
| *$N_2$* | - | - | - |
| *Other Solids* | - | - | - |
| *Other Solutes* | - | - | - |
| *Polylactic Acid* | - | - | - |
| *Sodium Citrate* | - | - | - |
| *Sulfuric Acid* | - | - | - |
| *Water* | 0.465008 | 0.726436 | 0.190615 |
| *Xylitol* | 0.464588 | 0.136083 | 0.809385 |
| *Xylose* | 0.0704042 | 0.137481 | - |
| Temperature (°C): | 5 | 5 | 5 |

**Design Data:**

| | | |
|---|---|---|
| Material | #N/A | |
| Application | #N/A | |
| Solid Flow | 12202.5 | kg/day |
| Liquid Flow | 12808 | kg/day |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 219,100.00 | **Equipment Weight (lbs)** | - |
| **Installation Cost:** | $ | 271,400.00 | **Installed Weight (lbs)** | 903.00 |
| **Comments:** | | | | |

# ROTARY DRUM FILTER

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Pretreatment Filter* | | Date: *7 April 2017* |
| | Item No. S-1 | | |
| | No. Required 1 | | By: Group 7 |
| **Function:** | Separates the BSG stream to be sent to xylitol and lactic acid fermentation paths | | |
| **Operation:** | | | |

| **Materials Handled:** | *Feed* | *Liquid Stream* | *Solid Stream* |
|---|---|---|---|
| Quantitiy (kg/day): | 518683 | 165777 | 352906 |
| Composition: | | | |
| *Ammonium Hydr.* | - | - | - |
| *$Ca(OH)_2$* | - | - | - |
| *$CaSO_4$* | - | - | - |
| *Cellulose Solid* | 0.0295048 | - | 0.0433647 |
| *$CH_2Cl_2$* | - | - | - |
| *Enzymes* | - | - | - |
| *Diphenyl Ether* | - | - | - |
| *Ferment. Sugars* | 3.56718E-05 | 0.00011161 | - |
| *Lactic Acid* | - | - | - |
| *Methanol* | - | - | - |
| *$N_2$* | - | - | - |
| *Other Solids* | 0.00752552 | - | 0.0110606 |
| *Other Solutes* | 0.0574568 | 0.17977 | - |
| *Polylactic Acid* | - | - | - |
| *Sodium Citrate* | - | - | - |
| *Sulfuric Acid* | 0.00260467 | 0.00814949 | - |
| *Water* | 0.877906 | 0.733856 | 0.945574 |
| *Xylitol* | - | - | - |
| *Xylose* | 0.0249656 | 0.0781123 | - |
| Temperature (°C): | 102.776 | 102.776 | 102.776 |

**Design Data:**

| | | |
|---|---|---|
| Material | SS316 | |
| Application | HI RATE | |
| Solid Flow | 352906 | kg/day |
| Liquid Flow | 165777 | kg/day |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 169,800.00 | **Equipment Weight (lbs)** | 7,500.00 |
| **Installation Cost:** | $ | 257,900.00 | **Installed Weight (lbs)** | 12,195.00 |
| **Comments:** | | | | |

# DISK CENTRIFUGE

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *LA Ferm. Centri.* | | | | |
| | Item No. S-10 | | | Date: *7 April 2017* | |
| | No. Required 1 | | | | |
| | | | | By: Group 7 | |
| **Function:** | Purifies lactic acid fermentation product | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Feed* | *Supernatent* | *Solids* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | #N/A | 366931 | 1391.28 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | 0.28 | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | - | 0.000379165 | - | | |
| *Lactic Acid* | - | 0.0375374 | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | 1 | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.72 | 0.962083 | - | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 25 | 37 | 37 | | |

**Design Data:**

Diameter #N/A meters

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | 0.35 | | |
| **Bare Module Cost:** | $ | 39,300.00 | **Equipment Weight (lbs)** | 2,900.00 |
| **Installation Cost:** | $ | 189,000.00 | **Installed Weight (lbs)** | 12,528.00 |
| **Comments:** | | | | |

# DISK CENTRIFUGE

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Xylitol Ferm. Centri.* | | | Date: *7 April 2017* | |
| | Item No. S-4 | | | | |
| | No. Required 1 | | | By: Group 7 | |
| **Function:** | Purifies xylitol fermentation product | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Feed* | *Supernatent* | *Solids* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | 175104 | 173766 | 1338.15 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | 0.0663634 | 0.0668744 | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | - | - | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | 0.00764203 | - | 1 | | |
| *Other Solutes* | 0.170195 | 0.171506 | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.745743 | 0.751485 | - | | |
| *Xylitol* | 0.0663634 | 0.0668744 | - | | |
| *Xylose* | 0.0100569 | 0.0101344 | - | | |
| Temperature (°C): | 32 | 32 | 32 | | |

**Design Data:**

Diameter #N/A meters

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 31,200.00 | **Equipment Weight (lbs)** | 2,300.00 |
| **Installation Cost:** | $ | 175,700.00 | **Installed Weight (lbs)** | 13,538.00 |
| **Comments:** | | | | |

# DISK CENTRIFUGE

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Sacch. Centrifuge* | | | Date: *7 April 2017* | |
| | Item No. S-6 | | | | |
| | No. Required 7 | | | By: Group 7 | |
| **Function:** | Removes solids in the stream exiting saccharification reactor | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Feed* | *Supernatent* | *Solids* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | 420005 | 368323 | 51682.6 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | 0.0199931 | - | 0.162476 | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | 0.0373114 | - | 0.303216 | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | 0.0364377 | 0.0415506 | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | 0.00912727 | - | 0.0741739 | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | 0.0123832 | - | 0.100633 | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.884747 | 0.958449 | 0.3595 | | |
| *Xylitol* | 0.0373114 | - | 0.303216 | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 25 | 25 | 25 | | |
| **Design Data:** | | | | | |
| | Diameter 0.254 | meters | | | |
| **Utilities (kW)** | | | No Utilities | | |
| **Bare Module Cost:** | $ 1,533,700.00 | | **Equipment Weight (lbs)** | | - |
| **Installation Cost:** | $ 1,899,700.00 | | **Installed Weight (lbs)** | | 6,320.00 |
| **Comments:** | | | | | |

# DISK CENTRIFUGE

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Neutr. Centrifuge* | | Date: *7 April 2017* |
| | Item No. S-5 | | |
| | No. Required 1 | | By: Group 7 |

**Function:** Removes calcium sulfate precipitated in neutrilization reactor

**Operation:**

| **Materials Handled:** | *Feed* | *Supernatent* | *Solids* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 173166 | 168700 | 4465.88 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | 0.000292413 | - | 0.0113384 | | |
| *$CaSO_4$* | 0.0102086 | - | 0.395842 | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | 0.000106848 | 0.000109676 | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | 0.1721 | 0.176656 | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | 0.000447262 | - | 0.0173427 | | |
| *Water* | 0.742066 | 0.746476 | 0.575477 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | 0.0747794 | 0.076759 | - | | |
| Temperature (°C): | 25 | 25 | 25 | | |

**Design Data:**

Diameter 0.254 meters

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 219,100.00 | **Equipment Weight (lbs)** | - |
| **Installation Cost:** | $ | 271,400.00 | **Installed Weight (lbs)** | 903.00 |

**Comments and Drawings:**

# CRYSTALLIZER

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *PLA Crystallizer* | | | Date: *7 April 2017* | |
| | Item No. S-8 | | | | |
| | No. Required 1 | | | By: Group 7 | |
| **Function:** | Removes water from the PLA recycle stream before it is introduced into reactor | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Feed* | *MeOH In* | *Liquor* | *PLA Out* | *Stream 3* |
| Quantitiy (kg/day): | 57571.3 | 69268.4 | 116169 | 10660.1 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | 0.8140174 | 0.478371 | 0.688654 | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | 0.000189944 | 0.000157868 | 9.41327E-05 | - | |
| *Ferment. Sugars* | - | - | - | - | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | 0.000628049 | 0.52147 | 0.311251 | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | - | - | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | 0.185162852 | - | - | 1 | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | - | - | - | - | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 40.1463 | 55.1613 | 25.8549 | 25.8549 | |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material | SS304 | | |
| Diameter | 1.0668 meters | Design Temp | 121.1111111 |
| Height | 3.6576 meters | Operating Temp | 25.85487722 |
| Volume | 3269.297609 liters | | |

| | | | |
|---|---|---|---|
| **Utilities (kW)** | No Utilities | | |
| **Bare Module Cost:** | $ 31,200.00 | **Equipment Weight (lbs)** | 2,300.00 |
| **Installation Cost:** | $ 166,100.00 | **Installed Weight (lbs)** | 10,478.00 |
| **Comments:** | | | |

# FLASH DRUM

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Lactic Acid Dryer* | | Date: *7 April 2017* | | |
| | Item No. S-14 | | | | |
| | No. Required 1 | | By: Group 7 | | |
| **Function:** | | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Mixed Feed* | *Distillate* | *Bottoms* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | 143964 | 118953 | 25010.3 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | 0.080718 | - | 0.464588 | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | - | - | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.90705 | 0.999996 | 0.465008 | | |
| *Xylitol* | 0.080718 | - | 0.464588 | | |
| *Xylose* | 0.0122323 | - | 0.0704042 | | |
| Temperature (°C): | 32 | 103.304 | 103.304 | | |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material SS304 | | | |
| Diameter 1.0668 | meters | Design Temp | 131.0813639 |
| Height 3.6576 | meters | Operating Temp | 103.3035861 |
| Volume 3269.297609 | liters | | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 31,200.00 | **Equipment Weight (lbs)** | 2,300.00 |
| **Installation Cost:** | $ | 175,700.00 | **Installed Weight (lbs)** | 13,538.00 |
| **Comments:** | | | | |

# FLASH DRUM

| | | |
|---|---|---|
| **Identification:** | **Item:** *Lactic Acid Dryer*<br>Item No. S-14<br>No. Required 1 | Date: *7 April 2017*<br><br>By: Group 7 |
| **Function:** | Removes water from the stream entering lactic acid process | |
| **Operation:** | | |

| **Materials Handled:** | *Mixed Feed* | *Distillate* | *Bottoms* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 352906 | 33762.5 | 319143 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | 0.0433647 | - | 0.0479523 | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | - | - | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | 0.0110606 | 0.00206905 | 0.0120119 | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.945574 | 0.997931 | 0.940035 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 102.776 | 110 | 110 | | |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material SS304 | | | |
| Diameter 1.2192 | meters | Design Temp | 137.7777778 |
| Height 3.81 | meters | Operating Temp | 110 |
| Volume 4448.023966 | liters | | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 33,600.00 | **Equipment Weight (lbs)** | 2,600.00 |
| **Installation Cost:** | $ | 192,900.00 | **Installed Weight (lbs)** | 15,954.00 |
| **Comments:** | | | | |

# TRAY DISTILLATION TOWER

| | | |
|---|---|---|
| **Identification:** | **Item:** *PLA Solvent Recover*<br>Item No. S-15<br>No. Required 1 | Date: *7 April 2017*<br><br>By: Group 7 |
| **Function:** | Separates the dichloromethane and methanol used in PLA purification | |
| **Operation:** | | |

| **Materials Handled:** | *Mixed Feed* | *Distillate* | *Bottoms* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 116169 | 46900.2 | 69268.4 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | 0.688654 | 0.999229 | 0.478371 | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | 9.41327E-05 | - | 0.000157868 | | |
| *Ferment. Sugars* | - | - | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | 0.311251 | 0.000770948 | 0.52147 | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | - | - | - | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 25.8549 | 40.1463 | 55.1613 | | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Material | SS304 | | Design Temp | 121.1111111 |
| Diameter | 1.0668 | meters | Oper. Temp | 63.2666 |
| Height | 10.9728 | meters | | |
| Trays | 12 | | Tray Type | SIEVE |
| Tray Spacing | 0.6096 | meters | | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 128,600.00 | **Equipment Weight (lbs)** | 10,800.00 |
| **Installation Cost:** | $ | 286,400.00 | **Installed Weight (lbs)** | 21,819.00 |
| **Comments:** | | | | |

# LIQUID EXTRACTION COLUMN

| | | |
|---|---|---|
| **Identification:** | **Item:** *Lac. Acid Extraction*<br>Item No. S-7<br>No. Required 1 | Date: *7 April 2017*<br><br>By: Group 7 |
| **Function:** | Transfers lactic acid from fermentation effluent into diphenyl ether solvent | |
| **Operation:** | | |

| **Materials Handled:** | *Ferm. Product* | *Solvent Input* | *Extract* | *Raffinate* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 366931 | 40407.5 | 53847.7 | 353084 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | - | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | - | - | |
| *Diphenyl Ether* | - | 0.989549 | 0.742835 | - | |
| *Ferment. Sugars* | 0.000379165 | 0.00344049 | 0.00258372 | - | |
| *Lactic Acid* | 0.0375374 | - | 0.247453 | 0.00127129 | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | - | - | - | - | |
| *Other Solutes* | - | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | - | - | - | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 0.962083 | 0.0070102 | 0.00712846 | 0.998729 | |
| *Xylitol* | - | - | - | - | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 37 | 155.79 | 22.0031 | 22.7 | |

**Design Data:**

Material

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 299,400.00 | **Equipment Weight (lbs)** | - |
| **Installation Cost:** | $ | 326,800.00 | **Installed Weight (lbs)** | 8,088.00 |
| **Comments and Drawings:** | | | | |

# FLASH DRUM

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *Ether Recovery Flash* | | |
| | Item No. S-13 | Date: *7 April 2017* | |
| | No. Required 1 | | |
| | | By: Group 7 | |
| **Function:** | Separates water from diphenyl ether so that ether can be recycled | | |
| **Operation:** | | | |

| **Materials Handled:** | *Mixed Feed* | *Distillate* | *Bottoms* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 42137.1 | 2739.82 | 39397.2 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | 0.948094 | 0.348745 | 0.989775 | | |
| *Ferment. Sugars* | 0.00329987 | - | 0.00352872 | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.0486057 | 0.651246 | 0.00669609 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 180 | 157.48 | 157.48 | | |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material SS304 | | | |
| Diameter 0.9144 | meters | Design Temp | 207.7777778 |
| Height 3.6576 | meters | Operating Temp | 180 |
| Volume 2401.932948 | liters | | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | -27.71 | |
| **Bare Module Cost:** | $ | 27,900.00 | **Equipment Weight (lbs)** | 2,000.00 |
| **Installation Cost:** | $ | 173,500.00 | **Installed Weight (lbs)** | 14,211.00 |
| **Comments:** | | | | |

# FLASH DRUM

| | | | |
|---|---|---|---|
| **Identification:** | **Item:** *PLA/Ether Flash*<br>Item No. S-12<br>No. Required 1 | Date: *7 April 2017*<br>By: Group 7 | |
| **Function:** | Separates the PLA from diphenyl ether solvent | | |
| **Operation:** | | | |

| **Materials Handled:** | *Mixed Feed* | *Distillate* | *Bottoms* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 52808.1 | 42137.1 | 10671.1 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | 0.756717 | 0.948094 | 0.00102476 | | |
| *Ferment. Sugars* | 0.00263459 | 0.00329987 | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | 0.201864 | - | 0.998966 | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.0387842 | 0.0486057 | - | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 288 | 288 | 288 | | |

**Design Data:**

| | | | |
|---|---|---|---|
| Shell Material | SS304 | | |
| Diameter | 0.9144 | meters | Design Temp 315.7777778 |
| Height | 3.6576 | meters | Operating Temp 288 |
| Volume | 2401.932948 | liters | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 27,900.00 | **Equipment Weight (lbs)** | 2,000.00 |
| **Installation Cost:** | $ | 185,600.00 | **Installed Weight (lbs)** | 15,391.00 |
| **Comments:** | | | | |

# DECANTER

| | | | | |
|---|---|---|---|---|
| **Identification:** | **Item:** | *Water/Ether Decant* | | |
| | Item No. | S-11 | Date: *7 April 2017* | |
| | No. Required | 1 | | |
| | | | By: Group 7 | |
| **Function:** | Separates water and diphenyl ether so that each can be recycled | | | |
| **Operation:** | | | | |

| **Materials Handled:** | *Mixed Feed* | *Ether Out* | *Water Out* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 3775.64 | 1010.29 | 2765.35 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | 0.262429 | 0.980741 | - | | |
| *Ferment. Sugars* | - | - | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | - | - | - | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.737564 | 0.0192589 | 0.999991 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 90 | 90 | 90 | | |

**Design Data:**

| | | | | |
|---|---|---|---|---|
| Shell Material | SS304 | | | |
| Diameter | 0.9144 | meters | Design Temp | 121.1111111 |
| Height | 3.6576 | meters | Operating Temp | 90 |
| Volume | 2401.932948 | liters | | |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | 8.5805 | | |
| **Bare Module Cost:** | $ | 27,700.00 | **Equipment Weight (lbs)** | 1,900.00 |
| **Installation Cost:** | $ | 170,800.00 | **Installed Weight (lbs)** | 12,772.00 |
| **Comments:** | | | | |

# AGITATED REACTOR

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Acid Hydrolysis* | | | | |
| | Item No. R-7 | | Date: *7 April 2017* | | |
| | No. Required 1 | | | | |
| | | | By: Group 7 | | |
| **Function:** | Performs acid hydrolysis to break down hemicellulose in the BSG | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *BSG Feed* | *Acid Feed* | *Exit Stream* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | 516332 | 2351 | 518683 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | 0.119997 | - | 0.0295048 | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | 3.51194E-05 | - | 3.56718E-05 | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | 0.00752552 | | |
| *Other Solutes* | - | - | 0.0574568 | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | 0.574649 | 0.00260467 | | |
| *Water* | 0.879967 | 0.425351 | 0.877906 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | 0.0249656 | | |
| Temperature (°C): | 150 | 25 | 150 | | |

**Design Data:**

| | | |
|---|---|---|
| Residence Time | 1.5 | hours |
| Shell Material | SS304 | |
| Diameter | 2.1336 | meters |
| Height | 7.9248 | meters |
| Volume | 28333.91261 | liters |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | No Utilities | | |
| **Bare Module Cost:** | $ 378,500.00 | **Equipment Weight (lbs)** | 50,900.00 | |
| **Installation Cost:** | $ 620,000.00 | **Installed Weight (lbs)** | 77,473.00 | |
| **Comments and Drawings:** | | Design temperature of 178C | | |

# AGITATED REACTOR

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Sacchar. Reactor* | | | | |
| | Item No. R-4 | | Date: *7 April 2017* | | |
| | No. Required 1 | | | | |
| | | | By: Group 7 | | |
| **Function:** | Uses enzymes to convert the cellulose in BSG to glucose for lactic acid process | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Solids Feed* | *Na Citr. Feed* | *Enzyme Feed* | *Exit Stream* | *Stream 3* |
| Quantitiy (kg/day): | 399133 | 5201 | 15671 | 420005 | |
| Composition: | | | | | |
| *Ammonium Hydr.* | 0.0210386 | - | - | 0.0199931 | |
| *$Ca(OH)_2$* | - | - | - | - | |
| *$CaSO_4$* | - | - | - | - | |
| *Cellulose Solid* | - | - | - | - | |
| *$CH_2Cl_2$* | - | - | - | - | |
| *Enzymes* | - | - | 1 | 0.0373114 | |
| *Diphenyl Ether* | - | - | - | - | |
| *Ferment. Sugars* | - | - | - | 0.0364377 | |
| *Lactic Acid* | - | - | - | - | |
| *Methanol* | - | - | - | - | |
| *$N_2$* | - | - | - | - | |
| *Other Solids* | 0.00960457 | - | - | 0.00912727 | |
| *Other Solutes* | 0.0383432 | - | - | - | |
| *Polylactic Acid* | - | - | - | - | |
| *Sodium Citrate* | - | 1 | - | 0.0123832 | |
| *Sulfuric Acid* | - | - | - | - | |
| *Water* | 0.931014 | - | - | 0.884747 | |
| *Xylitol* | - | - | 1 | 0.0373114 | |
| *Xylose* | - | - | - | - | |
| Temperature (°C): | 64.7913 | 25 | 25 | 25 | |

**Design Data:**

| | | |
|---|---|---|
| Residence Time | 1.5 | hours |
| Shell Material | SS304 | |
| Diameter | 1.0668 | meters |
| Height | 4.1148 | meters |
| Volume | 3677.959802 | liters |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | No Utilities | |
| **Bare Module Cost:** | $ | 115,100.00 | **Equipment Weight (lbs)** | 9,400.00 |
| **Installation Cost:** | $ | 290,900.00 | **Installed Weight (lbs)** | 24,684.00 |
| **Comments:** | | | | |

# AGITATED REACTOR

| | | | | |
|---|---|---|---|---|
| **Identification:** | **Item:** | *AAS Reactor* | | |
| | Item No. | R-3 | Date: *7 April 2017* | |
| | No. Required | 1 | | |
| | | | By: Group 7 | |
| **Function:** | Treats the cellulose solids in BSG so that they can be broken down by enzymes | | | |
| **Operation:** | | | | |

| **Materials Handled:** | *Cell. Feed* | *Ammonia Feed* | *Exit Stream* | *Stream 2* | *Stream 3* |
|---|---|---|---|---|---|
| Quantitiy (kg/day): | 319143 | 29990 | 349133 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | 0.28 | 0.0240516 | | |
| *$Ca(OH)_2$* | - | - | - | | |
| *$CaSO_4$* | - | - | - | | |
| *Cellulose Solid* | 0.0479523 | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | - | - | - | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | 0.0120119 | - | 0.0109801 | | |
| *Other Solutes* | - | - | 0.0438344 | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | - | - | - | | |
| *Water* | 0.940035 | 0.72 | 0.921134 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | - | - | - | | |
| Temperature (°C): | 110 | 25 | 70 | | |

**Design Data:**

| | | |
|---|---|---|
| Residence Time | 1.5 | hours |
| Shell Material | SS304 | |
| Diameter | 2.286 | meters |
| Height | 8.5344 | meters |
| Volume | 35028.18866 | liters |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | | -1988.8 | |
| **Bare Module Cost:** | $ | 408,300.00 | **Equipment Weight (lbs)** | 57,800.00 |
| **Installation Cost:** | $ | 649,600.00 | **Installed Weight (lbs)** | 84,050.00 |
| **Comments:** | | | Design temperature of 178 C | |

# AGITATED REACTOR

| | | | | | |
|---|---|---|---|---|---|
| **Identification:** | **Item:** *Neutraliz. Reactor* | | Date: *7 April 2017* | | |
| | Item No. R-1 | | | | |
| | No. Required 1 | | By: Group 7 | | |
| **Function:** | Neutralizes the sulfuric acid introduced in acid hydrolysis to raise pH to 2.5 | | | | |
| **Operation:** | | | | | |
| **Materials Handled:** | *Sugar Feed* | *CaOH2 Feed* | *Exit Stream* | *Stream 2* | *Stream 3* |
| Quantitiy (kg/day): | 165777 | 7388.62 | 173166 | | |
| Composition: | | | | | |
| *Ammonium Hydr.* | - | - | - | | |
| *$Ca(OH)_2$* | - | 0.137065 | 0.000292413 | | |
| *$CaSO_4$* | - | - | 0.0102086 | | |
| *Cellulose Solid* | - | - | - | | |
| *$CH_2Cl_2$* | - | - | - | | |
| *Enzymes* | - | - | - | | |
| *Diphenyl Ether* | - | - | - | | |
| *Ferment. Sugars* | 0.00011161 | - | 0.000106848 | | |
| *Lactic Acid* | - | - | - | | |
| *Methanol* | - | - | - | | |
| *$N_2$* | - | - | - | | |
| *Other Solids* | - | - | - | | |
| *Other Solutes* | 0.17977 | - | 0.1721 | | |
| *Polylactic Acid* | - | - | - | | |
| *Sodium Citrate* | - | - | - | | |
| *Sulfuric Acid* | 0.00814949 | - | 0.000447262 | | |
| *Water* | 0.733856 | 0.862935 | 0.742066 | | |
| *Xylitol* | - | - | - | | |
| *Xylose* | 0.0781123 | - | 0.0747794 | | |
| Temperature (°C): | 102.776 | 25 | 25 | | |

**Design Data:**

| | | |
|---|---|---|
| Residence Time | 1.5 | hours |
| Shell Material | SS304 | |
| Diameter | 0.762 | meters |
| Height | 3.5052 | meters |
| Volume | 1598.50861 | liters |

| | | | | |
|---|---|---|---|---|
| **Utilities (kW)** | | -745.51 | | |
| **Bare Module Cost:** | $ 98,700.00 | | **Equipment Weight (lbs)** | 6,000.00 |
| **Installation Cost:** | $ 270,800.00 | | **Installed Weight (lbs)** | 20,352.00 |
| **Comments:** | Design temperature of 178 C | | | |

**SIGMA-ALDRICH** sigma-aldrich.com

# SAFETY DATA SHEET

Version
4.9 Revision Date
05/27/2016 Print Date
03/19/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

| | | |
|---|---|---|
| Product name | : | Calcium hydroxide |
| Product Number | : | 31219 |
| Brand | : | Sigma-Aldrich |
| CAS-No. | : | 1305-62-0 |

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

| | | |
|---|---|---|
| Company | : | Sigma-Aldrich<br>3050 Spruce<br>Street<br>SAINT LOUIS MO 63103<br>USA |
| Telephone | : | +1 800-325-5832 |
| Fax | : | +1 800-325-5052 |

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

**GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**
Skin irritation (Category 2), H315
Serious eye damage (Category 1),
H318
Specific target organ toxicity - single exposure (Category 3), Respiratory system,
H335 Acute aquatic toxicity (Category 3), H402

For the full text of the H-Statements mentioned in this Section, see Section 16.

### 2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)

| | |
|---|---|
| H315 | Causes skin irritation. |
| H318 | Causes serious eye damage. |
| H335 | May cause respiratory irritation. |
| H402 | Harmful to aquatic life. |

Precautionary statement(s)

| | |
|---|---|
| P261 | Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray. |
| P264 | Wash skin thoroughly after handling. |
| P271 | Use only outdoors or in a well-ventilated area. |
| P273 | Avoid release to the environment. |
| P280 | Wear eye protection/ face protection. |
| P280 | Wear protective gloves. |
| P302 + P352 | IF ON SKIN: Wash with plenty of soap and water. |
| P304 + P340 + P312 | IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/ physician if you feel unwell. |
| P305 + P351 + P338 + P310 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER/doctor. |
| P332 + P313 | If skin irritation occurs: Get medical advice/ attention. |
| P362 | Take off contaminated clothing and wash before reuse. |
| P403 + P233 | Store in a well-ventilated place. Keep container tightly closed. |
| P405 | Store locked up. |
| P501 | Dispose of contents/ container to an approved waste disposal plant. |

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

| | | |
|---|---|---|
| Formula | : | $H_2CaO_2$ |
| Molecular weight | : | 74.09 g/mol |
| CAS-No. | : | 1305-62-0 |
| EC-No. | : | 215-137-3 |

**Hazardous components**

| Component | Classification | Concentration |
|---|---|---|
| **Calcium dihydroxide** | | |
| | Skin Irrit. 2; Eye Dam. 1; STOT SE 3; Aquatic Acute 3; H315, H318, H335, H402 | <= 100 % |

For the full text of the H-Statements mentioned in this Section, see Section 16.

## 4. FIRST AID MEASURES

### 4.1 Description of first aid measures

**General advice**

Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

#### If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

#### In case of skin contact

Wash off with soap and plenty of water. Consult a physician.

#### In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

#### If swallowed

Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed
No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture
No data available

### 5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information
No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.
For personal protection see section 8.

### 6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

### 6.3 Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections
For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.

Air and moisture sensitive. Keep in a dry place.
Storage class (TRGS 510): Non Combustible Solids

### 7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**

| Component | CAS-No. | Value | Control parameters | Basis |
|---|---|---|---|---|
| Calcium dihydroxide | 1305-62-0 | TWA | 5 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | Remarks | Upper Respiratory Tract irritation Eye irritation Skin irritation | | |
| | | TWA | 5.000000 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | | Upper Respiratory Tract irritation Eye irritation Skin irritation | | |
| | | TWA | 15.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | TWA | 5.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | TWA | 5.000000 mg/m3 | USA. NIOSH Recommended Exposure Limits |
| | | PEL | 5 mg/m3 | California permissible exposure limits for chemical contaminants (Title 8, Article 107) |

**8.2 Exposure controls**

**Appropriate engineering controls**
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

## Personal protective equipment Eye/face protection

Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: powder<br>Colour: beige |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | 12.4 - 12.6 at 20 °C (68 °F) |
| e) | Melting point/freezing point | >= 450 °C (>= 842 °F) |
| f) | Initial boiling point and boiling range | No data available |
| g) | Flash point | Not applicable |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | The product is not flammable. |
| j) | Upper/lower flammability or explosive limits | No data available |
| k) | Vapour pressure | No data available |
| l) | Vapour density | No data available |
| m) | Relative density | 2.24 g/cm3 at 25 °C (77 °F) |
| n) | Water solubility | 0.99 g/l at 20 °C (68 °F) |
| o) | Partition coefficient: n-octanol/water | No data available |
| p) | Auto-ignition temperature | No data available |
| q) | Decomposition temperature | No data available |

r) Viscosity — No data available

s) Explosive properties — No data available

t) Oxidizing properties — The substance or mixture is not classified as oxidizing.

## 9.2 Other safety information

| | |
|---|---|
| Bulk density | 200 - 800 kg/m3 |

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

No data available

### 10.5 Incompatible materials

Strong acids

### 10.6 Hazardous decomposition products

Hazardous decomposition products formed under fire conditions. - Calcium oxide
Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**
LD50 Oral - Rat - 7,340 mg/kg

Inhalation: No data available

No data available

### Skin corrosion/irritation

Skin - Rabbit
Result: Irritating to skin.
(OECD Test Guideline 404)

### Serious eye damage/eye irritation

Eyes - Rabbit
Result: Severe eye irritation
(OECD Test Guideline 405)

### Respiratory or skin sensitisation

No data available

### Germ cell mutagenicity

No data available

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

| | |
|---|---|
| OSHA: | No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA. |

### Reproductive toxicity

No data available

No data available

### Specific target organ toxicity - single exposure

Inhalation - May cause respiratory irritation.

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: EW2800000

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

| | |
|---|---|
| Toxicity to fish | LC50 - Clarias gariepinus - 33.884 mg/l - 96 h |
| Toxicity to daphnia and other aquatic invertebrates | EC50 - Daphnia magna (Water flea) - 49.1 mg/l - 48 h (OECD Test Guideline 202) |

| | |
|---|---|
| Toxicity to algae | EC50 - Pseudokirchneriella subcapitata (green algae) - 184.6 mg/l - 72 h (OECD Test Guideline 201) |

### 12.2 Persistence and degradability

The methods for determining biodegradability are not applicable to inorganic substances.

### 12.3 Bioaccumulative potential

Does not bioaccumulate.

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.
Harmful to aquatic life.

No data available

## 13. DISPOSAL CONSIDERATIONS

### 13.1 Waste treatment methods

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

Not dangerous goods

### IMDG

Not dangerous goods

### IATA

Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**

No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards

Acute Health Hazard

### Massachusetts Right To Know Components

Calcium dihydroxide

### Pennsylvania Right To Know Components

Calcium dihydroxide

### New Jersey Right To Know Components

Calcium dihydroxide

### California Prop. 65 Components

CAS-No. 1305-62-0 RevisionDate1994-04-01 94-04-01

CAS-No. 1305-62-0 RevisionDate1994-04-01

CAS-No. 1305-62-0 RevisionDate19

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**Full text of H-Statements referred to under sections 2 and 3.**

| | |
|---|---|
| Aquatic Acute | Acute aquatic toxicity |
| Eye Dam. | Serious eye damage |
| H315 | Causes skin irritation. |
| H318 | Causes serious eye damage. |
| H335 | May cause respiratory irritation. |
| H402 | Harmful to aquatic life. |
| Skin Irrit. | Skin irritation |
| STOT SE | Specific target organ toxicity - single exposure |

## HMIS Rating

| | |
|---|---|
| Health hazard: | 2 |
| Chronic Health Hazard: | |
| Flammability: | 0 |
| Physical Hazard | 0 |

**NFPA Rating**

| | |
|---|---|
| Health hazard: | 2 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

**Further information**


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

## Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 4.9 Revision Date: 05/27/2016 Print Date: 03/19/2017

# SAFETY DATA SHEET

Version
4.9 Revision Date
05/27/2016 Print Date
03/23/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

| | | |
|---|---|---|
| Product name | : | Calcium hydroxide |
| Product Number | : | 31219 |
| Brand | : | Sigma-Aldrich |
| CAS-No. | : | 1305-62-0 |

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

| | | |
|---|---|---|
| Company | : | Sigma-Aldrich<br>3050 Spruce<br>Street<br>SAINT LOUIS MO 63103<br>USA |
| Telephone | : | +1 800-325-5832 |
| Fax | : | +1 800-325-5052 |

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

**GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**
Skin irritation (Category 2), H315
Serious eye damage (Category 1),
H318
Specific target organ toxicity - single exposure (Category 3), Respiratory system,
H335 Acute aquatic toxicity (Category 3), H402

For the full text of the H-Statements mentioned in this Section, see Section 16.

### 2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)

| | |
|---|---|
| H315 | Causes skin irritation. |
| H318 | Causes serious eye damage. |
| H335 | May cause respiratory irritation. |

| | |
|---|---|
| H402 | Harmful to aquatic life. |

Precautionary statement(s)

| | |
|---|---|
| P261 | Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray. |
| P264 | Wash skin thoroughly after handling. |
| P271 | Use only outdoors or in a well-ventilated area. |
| P273 | Avoid release to the environment. |
| P280 | Wear eye protection/ face protection. |
| P280 | Wear protective gloves. |
| P302 + P352 | IF ON SKIN: Wash with plenty of soap and water. |
| P304 + P340 + P312 | IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/ physician if you feel unwell. |
| P305 + P351 + P338 + P310 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER/doctor. |
| P332 + P313 | If skin irritation occurs: Get medical advice/ attention. |
| P362 | Take off contaminated clothing and wash before reuse. |
| P403 + P233 | Store in a well-ventilated place. Keep container tightly closed. |
| P405 | Store locked up. |
| P501 | Dispose of contents/ container to an approved waste disposal plant. |

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

| | | |
|---|---|---|
| Formula | : | $H_2CaO_2$ |
| Molecular weight | : | 74.09 g/mol |
| CAS-No | : | 1305-62-0 |
| EC-No. | : | 215-137-3 |

**Hazardous components**

| Component | Classification | Concentration |
|---|---|---|
| **Calcium dihydroxide** | | |
| | Skin Irrit. 2; Eye Dam. 1; STOT SE 3; Aquatic Acute 3; H315, H318, H335, H402 | <= 100 % |

For the full text of the H-Statements mentioned in this Section, see Section 16.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures**

**General advice**
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

### If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

### In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

### In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

### If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

## 4.3 Indication of any immediate medical attention and special treatment needed

No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture

No data available

### 5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information

No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**

Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.

For personal protection see section 8.

### 6.2 Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

### 6.3 Methods and materials for containment and cleaning up

Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections

For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**

Avoid contact with skin and eyes. Avoid formation of dust and aerosols.Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.

Provide appropriate exhaust ventilation at places where dust is formed.

For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place.

Air and moisture sensitive. Keep in a dry place.

Storage class (TRGS 510): Non Combustible Solids

### 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**

| Component | CAS-No. | Value | Control parameters | Basis |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Calcium dihydroxide | 1305-62-0 | TWA | 5 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | Remarks | Upper Respiratory Tract irritation Eye irritation Skin irritation | | |
| | | TWA | 5.000000 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | | Upper Respiratory Tract irritation Eye irritation Skin irritation | | |
| | | TWA | 15.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | TWA | 5.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | TWA | 5.000000 mg/m3 | USA. NIOSH Recommended Exposure Limits |
| | | PEL | 5 mg/m3 | California permissible exposure limits for chemical contaminants (Title 8, Article 107) |

**8.2 Exposure controls**

**Appropriate engineering controls**
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

### Personal protective equipment Eye/face protection

Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: powder<br>Colour: beige |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | 12.4 - 12.6 at 20 °C (68 °F) |
| e) | Melting point/freezing point | >= 450 °C (>= 842 °F) |
| f) | Initial boiling point and boiling range | No data available |
| g) | Flash point | Not applicable |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | The product is not flammable. |
| j) | Upper/lower flammability or explosive limits | No data available |
| k) | Vapour pressure | No data available |
| l) | Vapour density | No data available |
| m) | Relative density | 2.24 g/cm3 at 25 °C (77 °F) |
| n) | Water solubility | 0.99 g/l at 20 °C (68 °F) |
| o) | Partition coefficient: n-octanol/water | No data available |
| p) | Auto-ignition temperature | No data available |
| q) | Decomposition temperature | No data available |

r) Viscosity — No data available

s) Explosive properties — No data available

t) Oxidizing properties — The substance or mixture is not classified as oxidizing.

## 9.2 Other safety information

| | |
|---|---|
| Bulk density | 200 - 800 kg/m3 |

# 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

## 10.2 Chemical stability

Stable under recommended storage conditions.

## 10.3 Possibility of hazardous reactions

No data available

## 10.4 Conditions to avoid

No data available

## 10.5 Incompatible materials

Strong acids

## 10.6 Hazardous decomposition products

Hazardous decomposition products formed under fire conditions. - Calcium oxide
Other decomposition products - No data available
In the event of fire: see section 5

# 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

LD50 Oral - Rat - 7,340 mg/kg

Inhalation: No data available

No data available

## Skin corrosion/irritation

Skin - Rabbit
Result: Irritating to skin.
(OECD Test Guideline 404)

## Serious eye damage/eye irritation

Eyes - Rabbit
Result: Severe eye irritation
(OECD Test Guideline 405)

## Respiratory or skin sensitisation

No data available

## Germ cell mutagenicity

No data available

## Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

| | |
|---|---|
| OSHA: | No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA. |

### Reproductive toxicity

No data available

No data available

### Specific target organ toxicity - single exposure

Inhalation - May cause respiratory irritation.

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: EW2800000

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

| | |
|---|---|
| Toxicity to fish | LC50 - Clarias gariepinus - 33.884 mg/l - 96 h |
| Toxicity to daphnia and other aquatic invertebrates | EC50 - Daphnia magna (Water flea) - 49.1 mg/l - 48 h (OECD Test Guideline 202) |

| | |
|---|---|
| Toxicity to algae | EC50 - Pseudokirchneriella subcapitata (green algae) - 184.6 mg/l - 72 h (OECD Test Guideline 201) |

### 12.2 Persistence and degradability
The methods for determining biodegradability are not applicable to inorganic substances.

### 12.3 Bioaccumulative potential
Does not bioaccumulate.

### 12.4 Mobility in soil
No data available

### 12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects
An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.
Harmful to aquatic life.

No data available

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Product**
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

### Contaminated packaging
Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**
Not dangerous goods

### IMDG
Not dangerous goods

### IATA
Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components
This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards
Acute Health Hazard

### Massachusetts Right To Know Components

Calcium dihydroxide

### Pennsylvania Right To Know Components

Calcium dihydroxide

### New Jersey Right To Know Components

Calcium dihydroxide

### California Prop. 65 Components

CAS-No. 1305-62-0

CAS-No. 1305-62-0

CAS-No. 1305-62-0

RevisionDate1994-04-01

94-04-01

RevisionDate1994-04-01

RevisionDate19

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**Full text of H-Statements referred to under sections 2 and 3.**

| | |
|---|---|
| Aquatic Acute | Acute aquatic toxicity |
| Eye Dam. | Serious eye damage |
| H315 | Causes skin irritation. |
| H318 | Causes serious eye damage. |
| H335 | May cause respiratory irritation. |
| H402 | Harmful to aquatic life. |
| Skin Irrit. | Skin irritation |
| STOT SE | Specific target organ toxicity - single exposure |

## HMIS Rating

| | |
|---|---|
| Health hazard: | 2 |
| Chronic Health Hazard: | |
| Flammability: | 0 |
| Physical Hazard | 0 |

**NFPA Rating**

| | |
|---|---|
| Health hazard: | 2 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

**Further information**


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

## Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 4.9 Revision Date: 05/27/2016 Print Date: 03/23/2017

# SAFETY DATA SHEET

Version
3.6 Revision Date
12/02/2015 Print Date
03/19/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

Product name : Calcium sulfate dihydrate

Product Number : C3771
Brand : Sigma-Aldrich

CAS-No. : 10101-41-4

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce
Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

Not a hazardous substance or mixture.

### 2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

Formula : $CaO_4S \cdot 2H_2O$
Molecular weight : 172.17 g/mol
CAS-No. : 10101-41-4
EC-No. : 231-900-3

**Hazardous components**

| Component | Classification | Concentration |
|---|---|---|

| Calcium sulfate | | |
|---|---|---|
| | | <= 100 % |

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures If**

**inhaled**
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

### In case of skin contact

Wash off with soap and plenty of water.

### In case of eye contact

Flush eyes with water as a precaution.

### If swallowed

Never give anything by mouth to an unconscious person. Rinse mouth with water.

### 4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed

No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture

Sulphur oxides, Calcium oxide

### 5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information

No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

### 6.2 Environmental precautions

Do not let product enter drains.

### 6.3 Methods and materials for containment and cleaning up

Sweep up and shovel. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections

For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place.

Keep in a dry place. Keep in a dry place.

### 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

### 8.1 Control parameters

**Components with workplace control parameters**

| Component | CAS-No. | Value | Control parameters | Basis |
|---|---|---|---|---|
| Calcium sulfate | 10101-41-4 | TWA | 15.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | TWA | 5.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | TWA | 10.000000 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | Remarks | Nasal symptoms | | |
| | | TWA | 5.000000 mg/m3 | USA. NIOSH Recommended Exposure Limits |
| | | Gypsum is the dihydrate form & Plaster of Paris is the hemihydrate form. | | |
| | | TWA | 10.000000 mg/m3 | USA. NIOSH Recommended Exposure Limits |
| | | Gypsum is the dihydrate form & Plaster of Paris is the hemihydrate form. | | |
| | | TWA | 10.000000 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | | Nasal symptoms | | |
| | | TWA | 10 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | | Nasal symptoms | | |

### 8.2 Exposure controls

**Appropriate engineering controls**

General industrial hygiene practice.

#### Personal protective equipment Eye/face protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

#### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Do not let product enter drains.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: powder<br>Colour: white |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | No data available |
| e) | Melting point/freezing point | No data available |
| f) | Initial boiling point and boiling range | No data available |
| g) | Flash point | Not applicable |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | No data available |
| j) | Upper/lower flammability or explosive limits | No data available |
| k) | Vapour pressure | No data available |
| l) | Vapour density | No data available |
| m) | Relative density | 2.320 g/cm3 |
| n) | Water solubility | No data available |
| o) | Partition coefficient: n-octanol/water | No data available |
| p) | Auto-ignition temperature | No data available |
| q) | Decomposition temperature | No data available |

r) Viscosity No data available

s) Explosive properties No data available

t) Oxidizing properties No data available

### 9.2 Other safety information

No data available

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

Avoid moisture.

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

No data available

Inhalation: No data available

Dermal: No data available

No data available

### Skin corrosion/irritation

No data available

### Serious eye damage/eye irritation

No data available

### Respiratory or skin sensitisation

No data available

### Germ cell mutagenicity

No data available

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

## Reproductive toxicity

No data available

No data available

## Specific target organ toxicity - single exposure

No data available

## Specific target organ toxicity - repeated exposure

No data available

## Aspiration hazard

No data available

## Additional Information

RTECS: EW4150000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

No data available

### 12.2 Persistence and degradability

No data available

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

No data available

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company.

## Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

Not dangerous goods

### IMDG

Not dangerous goods

### IATA

Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**

No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

## SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

## SARA 311/312 Hazards

No SARA Hazards

## Massachusetts Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Calcium sulfate | 10101-41-4 | 1994-04-01 |

**Pennsylvania Right To Know Components**

| | CAS-No. | Revision Date |
|---|---|---|
| Calcium sulfate | 10101-41-4 | 1994-04-01 |

**New Jersey Right To Know Components**

| | CAS-No | Revision Date |
|---|---|---|
| Calcium sulfate | 10101-41-4 | 1994-04-01 |

**California Prop. 65 Components**

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**HMIS Rating**

| | |
|---|---|
| Health hazard: | 0 |
| Chronic Health Hazard: | |
| Flammability: | 0 |
| Physical Hazard | 0 |

### NFPA Rating

| | |
|---|---|
| Health hazard: | 0 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

### Further information


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 3.6 Revision Date: 12/02/2015 Print Date: 03/19/2017

# SAFETY DATA SHEET

Version
4.7 Revision Date
05/23/2016 Print Date
03/18/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

Product name : Diphenyl ether

Product Number : 240834
Brand : Aldrich

CAS-No. : 101-84-8

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce
Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

**GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**
Eye irritation (Category 2A), H319
Acute aquatic toxicity (Category 2), H401
Chronic aquatic toxicity (Category 2),
H411

For the full text of the H-Statements mentioned in this Section, see Section 16.

### 2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Warning

Hazard statement(s)
H319 Causes serious eye irritation.
H411 Toxic to aquatic life with long lasting effects.

Precautionary statement(s)

| | |
|---|---|
| P264 | Wash skin thoroughly after handling. |
| P273 | Avoid release to the environment. |
| P280 | Wear eye protection/ face protection. |
| P305 + P351 + P338 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. |
| P337 + P313 | If eye irritation persists: Get medical advice/ attention. |
| P391 | Collect spillage. |
| P501 | Dispose of contents/ container to an approved waste disposal plant. |

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

Synonyms : Phenyl ether
Diphenyl oxide

Formula : $C_{12}H_{10}O$
Molecular weight : 170.21 g/mol
CAS-No. : 101-84-8
EC-No. : 202-981-2

### Hazardous components

| Component | Classification | Concentration |
|---|---|---|
| **Diphenyl ether** | | |
| | Eye Irrit. 2A; Aquatic Acute 2; Aquatic Chronic 2; H319, H411 | <= 100 % |

For the full text of the H-Statements mentioned in this Section, see Section 16.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures**

**General advice**
Consult a physician. Show this safety data sheet to the doctor in attendance.

### If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

### In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

### In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

### If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed
No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

## 5.2 Special hazards arising from the substance or mixture

No data available

## 5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary.

## 5.4 Further information

No data available

# 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**

Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Avoid breathing dust.
For personal protection see section 8.

## 6.2 Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

## 6.3 Methods and materials for containment and cleaning up

Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

## 6.4 Reference to other sections

For disposal see section 13.

# 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**

Avoid contact with skin and eyes. Avoid formation of dust and aerosols.Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

**7.2 Conditions for safe storage, including any incompatibilities** Keep container tightly closed in a dry and well-ventilated place. Storage class (TRGS 510): Non Combustible Solids

## 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

# 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**

| Component | CAS-No. | Value | Control parameters | Basis |
|---|---|---|---|---|
| Diphenyl ether | 101-84-8 | TWA | 1.000000 ppm | USA. ACGIH Threshold Limit Values (TLV) |
| | Remarks | Eye & Upper Respiratory Tract irritation Nausea | | |
| | | STEL | 2.000000 ppm | USA. ACGIH Threshold Limit Values (TLV) |
| | | Eye & Upper Respiratory Tract irritation Nausea | | |
| | | TWA | 1.000000 ppm 7.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | The value in mg/m3 is approximate. | | |

| | | | | |
|---|---|---|---|---|
| | | TWA | 1.000000 ppm 7.000000 mg/m3 | USA. NIOSH Recommended Exposure Limits |
| | | TWA | 1.000000 ppm 7.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | The value in mg/m3 is approximate. | | |
| | | TWA | 1.000000 ppm | USA. ACGIH Threshold Limit Values (TLV) |
| | | Upper Respiratory Tract irritation | | |
| | | Eye irritation Nausea | | |
| | | STEL | 2.000000 ppm | USA. ACGIH Threshold Limit Values (TLV) |
| | | Upper Respiratory Tract irritation Eye irritation Nausea | | |
| | | TWA | 1.000000 ppm 7.000000 mg/m3 | USA. NIOSH Recommended Exposure Limits |
| | | PEL | 1 ppm 7 mg/m3 | California permissible exposure limits for chemical contaminants (Title 8, Article 107) |

### 8.2 Exposure controls

**Appropriate engineering controls**
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

#### Personal protective equipment Eye/face protection

Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

#### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: butyl-rubber
Minimum layer thickness: 0.3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

Splash contact
Material: butyl-rubber
Minimum layer thickness: 0.3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator.For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

---

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: crystalline<br>Colour: white |
| b) | Odour | unpleasant |
| c) | Odour Threshold | No data available |
| d) | pH | No data available |
| e) | Melting point/freezing point | Melting point/range: 25 - 27 °C (77 - 81 °F) - lit. |
| f) | Initial boiling point and boiling range | 259 °C (498 °F) - lit. |
| g) | Flash point | 115 °C (239 °F) - closed cup |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | No data available |
| j) | Upper/lower flammability or explosive limits | Upper explosion limit: 1.5 %(V)<br>Lower explosion limit: 0.8 %(V) |
| k) | Vapour pressure | 1,013 hPa (760 mmHg) at 257.9 °C (496.2 °F)<br>< 1 hPa (< 1 mmHg) at 20 °C (68 °F) |
| l) | Vapour density | No data available |
| m) | Relative density | 1.073 g/mL at 25 °C (77 °F) |
| n) | Water solubility | No data available |
| o) | Partition coefficient: n-octanol/water | log Pow: 4.21 at 25 °C (77 °F) |
| p) | Auto-ignition temperature | No data available |
| q) | Decomposition temperature | No data available |

r) Viscosity
No data available

s) Explosive properties
No data available

t) Oxidizing properties
No data available

## 9.2 Other safety information
No data available

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**
No data available

### 10.2 Chemical stability
Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions
No data available

### 10.4 Conditions to avoid
No data available

### 10.5 Incompatible materials
Strong oxidizing agents

### 10.6 Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Carbon oxides Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

$LD_{50}$ Oral - Rat - 3,370 mg/kg

Inhalation: No data available LD50 Dermal - Rabb

it - > 5,000 mg/kg No data available

## Skin corrosion/irritation

Skin - Rabbit
Result: Mild skin irritation - 24 h

## Serious eye damage/eye irritation

Eyes - Rabbit
Result: Irritating to eyes.

## Respiratory or skin sensitisation

No data available

## Germ cell mutagenicity

No data available

## Carcinogenicity

| | |
|---|---|
| IARC: | No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC. |
| NTP: | No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP. |
| OSHA: | No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA. |

## Reproductive toxicity

No data available

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ch - Irregularities - Based on Human Evidence Stomach - Irregularities - Based on Human Evidence

## 12. ECOLOGICAL INFORMATION

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### 12.1 Toxicity

Toxicity to fish LC50 - Cyprinodon variegatus (sheepshead minnow) - 1.0 - 2.4 mg/l - 96.0 h

Toxicity to daphnia and other aquatic invertebrates

## Specific target organ toxicity - single exposure

No data available

## Specific target organ toxicity - repeated exposure

No data available

## Aspiration hazard

No data available

## Additional Information

RTECS: KN8970000

prolonged or repeated exposure can cause:, Dermatitis, Liver injury may occur., To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

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.0 h EC50 - Daphnia magna (Water flea) - 1.7 mg/l - 48 h

## 12.2 Persistence and degradability

Ratio BOD/ThBOD 62 %

## 12.3 Bioaccumulative potential

Bioaccumulation Oncorhynchus mykiss (rainbow trout) - 7 d
- 16 µg/l

Bioconcentration factor (BCF): 470

Indication of bioaccumulation.

## 12.4 Mobility in soil

No data available

## 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

## 12.6 Other adverse effects

An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.
Toxic to aquatic life with long lasting effects.

# 13. DISPOSAL CONSIDERATIONS

## 13.1 Waste treatment methods

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

## Contaminated packaging

Dispose of as unused product.

# 14. TRANSPORT INFORMATION

**DOT (US)**

Not dangerous goods

### IMDG

UN number: 3077 Class: 9 Packing group: III EMS-No: F-A, S-F
Proper shipping name: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S. (Diphenyl ether)
Marine pollutant:yes

### IATA

UN number: 3077 Class: 9 Packing group: III
Proper shipping name: Environmentally hazardous substance, solid, n.o.s. (Diphenyl ether)

### Further information

EHS-Mark required (ADR 2.2.9.1.10, IMDG code 2.10.3) for single packagings and combination packagings containing inner packagings with Dangerous Goods > 5L for liquids or > 5kg for solids.

# 15. REGULATORY INFORMATION

**SARA 302 Components**

No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

## SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

## SARA 311/312 Hazards

Acute Health Hazard, Chronic Health Hazard**Massachusetts Right To Know Components** CAS-No. Revision Date

| | | |
|---|---|---|
| Diphenyl ether | 101-84-8 | 2007-03-01 |

**Pennsylvania Right To Know Components**

| | CAS-No. | Revision Date |
|---|---|---|
| Diphenyl ether | 101-84-8 | 2007-03-01 |

**New Jersey Right To Know Components**

| | CAS-No. | Revision Date |
|---|---|---|
| Diphenyl ether | 101-84-8 | 2007-03-01 |

**California Prop. 65 Components**

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**Full text of H-Statements referred to under sections 2 and 3.**

| | |
|---|---|
| Aquatic Acute | Acute aquatic toxicity |
| Aquatic Chronic | Chronic aquatic toxicity |
| Eye Irrit. | Eye irritation |
| H319 | Causes serious eye irritation. |
| H401 | Toxic to aquatic life. |
| H411 | Toxic to aquatic life with long lasting effects. |

### HMIS Rating

| | |
|---|---|
| Health hazard: | 2 |
| Chronic Health Hazard: | * |
| Flammability: | 1 |
| Physical Hazard | 0 |

**NFPA Rating**

| | |
|---|---|
| Health hazard: | 2 |
| Fire Hazard: | 1 |
| Reactivity Hazard: | 0 |

**Further information**


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 4.7 Revision Date: 05/23/2016 Print Date: 03/18/2017

# SAFETY DATA SHEET

Version 4.10
Revision Date 02/17/2017
Print Date 03/18/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

Product name : Furfural

Product Number : 185914
Brand : Sigma-Aldrich
Index-No. : 605-010-00-4

CAS-No. : 98-01-1

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

**GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**
Flammable liquids (Category 4), H227
Acute toxicity, Oral (Category 3), H301
Acute toxicity, Inhalation (Category 2), H330
Acute toxicity, Dermal (Category 4), H312
Eye irritation (Category 2A), H319
Carcinogenicity (Category 2), H351
Acute aquatic toxicity (Category 3), H402

For the full text of the H-Statements mentioned in this Section, see Section 16.

### 2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)
H227 Combustible liquid.
H301 Toxic if swallowed.

| | |
|---|---|
| H312 | Harmful in contact with skin. |
| H319 | Causes serious eye irritation. |
| H330 | Fatal if inhaled. |
| H351 | Suspected of causing cancer. |
| H402 | Harmful to aquatic life. |

Precautionary statement(s)

| | |
|---|---|
| P201 | Obtain special instructions before use. |
| P202 | Do not handle until all safety precautions have been read and understood. |
| P210 | Keep away from heat/sparks/open flames/hot surfaces. No smoking. |
| P260 | Do not breathe dust/ fume/ gas/ mist/ vapours/ spray. |
| P264 | Wash skin thoroughly after handling. |
| P270 | Do not eat, drink or smoke when using this product. |
| P271 | Use only outdoors or in a well-ventilated area. |
| P273 | Avoid release to the environment. |
| P280 | Wear protective gloves/ protective clothing/ eye protection/ face protection. |
| P284 | Wear respiratory protection. |
| P301 + P310 + P330 | IF SWALLOWED: Immediately call a POISON CENTER/doctor. Rinse mouth. |
| P302 + P352 + P312 | IF ON SKIN: Wash with plenty of water.Call a POISON CENTER/doctor if you feel unwell. |
| P304 + P340 + P310 | IF INHALED: Remove person to fresh air and keep comfortable for breathing. Immediately call a POISON CENTER/doctor. |
| P305 + P351 + P338 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. |
| P308 + P313 | IF exposed or concerned: Get medical advice/ attention. |
| P337 + P313 | If eye irritation persists: Get medical advice/ attention. |
| P363 | Wash contaminated clothing before reuse. |
| P370 + P378 | In case of fire: Use dry sand, dry chemical or alcohol-resistant foam to extinguish. |
| P403 + P233 | Store in a well-ventilated place. Keep container tightly closed. |
| P403 + P235 | Store in a well-ventilated place. Keep cool. |
| P405 | Store locked up. |
| P501 | Dispose of contents/ container to an approved waste disposal plant. |

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS

Photosensitizer.

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

### 3.1 Substances

| | | |
|---|---|---|
| Synonyms | : | 2-Furaldehyde<br>Furan-2-carboxaldehyde |
| Formula | : | $C_5H_4O_2$ |
| Molecular weight | : | 96.08 g/mol |
| CAS-No. | : | 98-01-1 |
| EC-No. | : | 202-627-7 |
| Index-No. | : | 605-010-00-4 |

### Hazardous components

| Component | Classification | Concentration |
|---|---|---|
| **2-Furaldehyde** | | |
| | Flam. Liq. 4; Acute Tox. 3; Acute Tox. 2; Acute Tox. 4; Eye Irrit. 2A; Carc. 2; Aquatic Acute 3; H227, H301, H312, H319, H330, H351, H402 | 90 - 100 % |

For the full text of the H-Statements mentioned in this Section, see Section 16.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures**

**General advice**
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

### If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

### In case of skin contact
Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.

### In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

### If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed
No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture
No data available

### 5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information
Use water spray to cool unopened containers.

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Wear respiratory protection. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Remove all sources of ignition. Evacuate personnel to safe areas. Beware of vapours accumulating to form explosive concentrations. Vapours can accumulate in low areas.
For personal protection see section 8.

### 6.2 Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

### 6.3 Methods and materials for containment and cleaning up
Contain spillage, and then collect with an electrically protected vacuum cleaner or by wet-brushing and place in container for disposal according to local regulations (see section 13). Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections
For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**

Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking.Take measures to prevent the build up of electrostatic charge. For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

### 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

### 8.1 Control parameters

**Components with workplace control parameters**

| Component | CAS-No. | Value | Control parameters | Basis |
|---|---|---|---|---|
| 2-Furaldehyde | 98-01-1 | TWA | 2 ppm | USA. ACGIH Threshold Limit Values (TLV) |
| | Remarks | Upper Respiratory Tract irritation Eye irritation<br>Substances for which there is a Biological Exposure Index or Indices (see BEI® section)<br>Confirmed animal carcinogen with unknown relevance to humans Danger of cutaneous absorption | | |
| | | TWA | 2.000000 ppm | USA. ACGIH Threshold Limit Values (TLV) |
| | | Upper Respiratory Tract irritation Eye irritation<br>Substances for which there is a Biological Exposure Index or Indices (see BEI® section)<br>Confirmed animal carcinogen with unknown relevance to humans Danger of cutaneous absorption | | |
| | | TWA | 5.000000 ppm<br>20.000000 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |
| | | Skin designation<br>The value in mg/m3 is approximate | | |
| | | See Appendix D - Substances with No Established RELs | | |
| | | PEL | 2 ppm<br>8 mg/m3 | California permissible exposure limits for chemical contaminants (Title 8, Article 107) |
| | | Skin | | |

**Biological occupational exposure limits**

| Component | CAS-No. | Parameters | Value | Biological specimen | Basis |
|---|---|---|---|---|---|
| 2-Furaldehyde | 98-01-1 | Furoic acid | 200.0000 mg/l | In urine | ACGIH - Biological Exposure Indices (BEI) |
| | Remarks | End of shift (As soon as possible after exposure ceases) | | | |

### 8.2 Exposure controls

**Appropriate engineering controls**
Avoid contact with skin, eyes and clothing. Wash hands before breaks and immediately after handling the product.

#### Personal protective equipment Eye/face protection

Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: butyl-rubber
Minimum layer thickness: 0.3 mm
Break through time: 480 min
Material tested:Butoject® (KCL 897 / Aldrich Z677647, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.4 mm
Break through time: 30 min
Material tested:Camatril® (KCL 730 / Aldrich Z677442, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: clear, viscous, liquid<br>Colour: light brown |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | No data available |
| e) | Melting point/freezing point | Melting point/range: -36 °C (-33 °F) - lit. |
| f) | Initial boiling point and boiling range | 162 °C (324 °F) - lit. |
| g) | Flash point | 61.7 °C (143.1 °F) - closed cup |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | No data available |
| j) | Upper/lower flammability or explosive limits | Upper explosion limit: 19.3 %(V)<br>Lower explosion limit: 2.1 %(V) |

k) Vapour pressure
18.0 hPa (13.5 mmHg) at 55 °C (131 °F)

No data available

No data available

2.3 hPa (1.7 mmHg) at 20 °C (68 °F)

l) Vapour density
3.32 - (Air = 1.0)

m) Relative density
1.16 g/cm3 at 25 °C (77 °F)

n) Water solubility
soluble

o) Partition coefficient: n-
log Pow: 0.41
octanol/water

p) Auto-ignition temperature

q) Decomposition temperature

r) Viscosity — No data available

s) Explosive properties — No data available

t) Oxidizing properties — No data available

## 9.2 Other safety information

| | |
|---|---|
| Surface tension | 43.5 mN/m at 20 °C (68 °F) |
| Relative vapour density | 3.32 - (Air = 1.0) |

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**
No data available

### 10.2 Chemical stability
Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions
No data available

### 10.4 Conditions to avoid
Heat, flames and sparks.

### 10.5 Incompatible materials
Oxidizing agents, Strong acids

### 10.6 Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Carbon oxides
Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**
LD50 Oral - Rat - male - 145 - 204 mg/kg

LD50 Oral - Rat - female - 90 - 119 mg/kg

LC50 Inhalation - Rat - male and female - 4 h - > 0.54 - < 1.63 mg/l
(OECD Test Guideline 403)

LD50 Dermal - Rabbit - > 2,000 mg/kg
(OECD Test Guideline 402)
Remarks: Classified according to Regulation (EU) 1272/2008, Annex VI (Table 3.1/3.2)

No data available

### Skin corrosion/irritation
Skin - Rabbit
Result: Mild skin irritation - 24 h
(OECD Test Guideline 404)

### Serious eye damage/eye irritation
Eyes - Rabbit
Result: Moderate eye irritation - 24 h
(OECD Test Guideline 405)

### Respiratory or skin sensitisation
Maximisation Test - Guinea pig

Did not cause sensitisation on laboratory animals.
(OECD Test Guideline 406)

## Germ cell mutagenicity

Mouse
lymphocyte
Mutation in mammalian somatic cells.

Human
HeLa cell
DNA inhibition

Human
lymphocyte
Sister chromatid exchange

## Carcinogenicity

Carcinogenicity - Rat - Oral
Tumorigenic:Equivocal tumorigenic agent by RTECS criteria. Liver:Tumors.

This product is or contains a component that has been reported to be possibly carcinogenic based on its IARC, ACGIH, NTP, or EPA classification.

Limited evidence of carcinogenicity in animal studies

| | |
|---|---|
| IARC: | No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC. |
| NTP: | No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP. |
| OSHA: | No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA. |

## Reproductive toxicity

No data available

No data available

## Specific target organ toxicity - single exposure

No data available

## Specific target organ toxicity - repeated exposure

No data available

## Aspiration hazard

No data available

## Additional Information

RTECS: LT7000000

Central nervous system depression, Headache, Material is extremely destructive to tissue of the mucous membranes and upper respiratory tract, eyes, and skin., Cough

Stomach - Irregularities - Based on Human Evidence
Stomach - Irregularities - Based on Human Evidence

# 12. ECOLOGICAL INFORMATION

### 12.1 Toxicity

| | |
|---|---|
| Toxicity to fish | LC50 - Pimephales promelas (fathead minnow) - 32 mg/l - 96 h |
| Toxicity to daphnia and other aquatic | nvertebrates |

| | |
|---|---|
| Toxicity to algae | EC50 - other microorganisms - 570 mg/l - 24 h |

### 12.2 Persistence and degradability

| | |
|---|---|
| Biodegradability | aerobic Biochemical oxygen demand - Exposure time 28 d<br>Result: 93.5 % - Readily biodegradable.<br>(OECD Test Guideline 301C) |

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.
Harmful to aquatic life.

No data available

## 13. DISPOSAL CONSIDERATIONS

### 13.1 Waste treatment methods

**Product**

This combustible material may be burned in a chemical incinerator equipped with an afterburner and scrubber. Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

#### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

UN number: 1199 Class: 6.1 (3) Packing group: II
Proper shipping name: Furaldehydes
Reportable Quantity (RQ): 5000 lbs
Poison Inhalation Hazard: No

#### IMDG

UN number: 1199 Class: 6.1 (3) Packing group: II EMS-No: F-E, S-D
Proper shipping name: FURALDEHYDES

#### IATA

UN number: 1199 Class: 6.1 (3) Packing group: II
Proper shipping name: Furaldehydes

## 15. REGULATORY INFORMATION

**SARA 302 Components**

No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

#### SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

#### SARA 311/312 Hazards

Fire Hazard, Acute Health Hazard, Chronic Health Hazard

## New Jersey Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| 2-Furaldehyde | 98-01-1 | 1993-04-24 |

## California Prop. 65 Components

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**Full text of H-Statements referred to under sections 2 and 3.**

| | |
|---|---|
| Acute Tox. | Acute toxicity |
| Aquatic Acute | Acute aquatic toxicity |
| Carc. | Carcinogenicity |
| Eye Irrit. | Eye irritation |
| Flam. Liq. | Flammable liquids |
| H227 | Combustible liquid. |
| H301 | Toxic if swallowed. |
| H312 | Harmful in contact with skin. |
| H319 | Causes serious eye irritation. |
| H330 | Fatal if inhaled. |
| H351 | Suspected of causing cancer. |
| H402 | Harmful to aquatic life. |

## HMIS Rating

| | |
|---|---|
| Health hazard: | 2 |
| Chronic Health Hazard: | * |
| Flammability: | 2 |
| Physical Hazard | 0 |

**NFPA Rating**

| | |
|---|---|
| Health hazard: | 2 |
| Fire Hazard: | 2 |
| Reactivity Hazard: | 0 |

**Further information**


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

## Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 4.10 Revision Date: 02/17/2017 Print Date: 03/18/2017

# SAFETY DATA SHEET

Version
5.3 Revision Date
04/06/2016 Print Date
03/18/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

Product name : Glucose solution

Product Number : 49163
Brand : Sigma

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce
Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

Not a hazardous substance or mixture.

### 2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.2 Mixtures**

Formula : $C_6H_{12}O_6$
Molecular weight : 180.16 g/mol

No components need to be disclosed according to the applicable regulations.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures If**

**inhaled**
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

### In case of skin contact
Wash off with soap and plenty of water.

### In case of eye contact
Flush eyes with water as a precaution.

### If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed
No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture
No data available

### 5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information
No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Avoid breathing vapours, mist or gas.
For personal protection see section 8.

### 6.2 Environmental precautions
Do not let product enter drains.

### 6.3 Methods and materials for containment and cleaning up
Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections
For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**
For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.

### 7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**
Contains no substances with occupational exposure limit values.

## 8.2 Exposure controls

**Appropriate engineering controls**
General industrial hygiene practice.

### Personal protective

#### equipment Eye/face

#### protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

#### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

#### Body Protection

Impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

#### Respiratory protection

Respiratory protection not required. For nuisance exposures use type OV/AG (US) or type ABEK (EU EN 14387) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

#### Control of environmental exposure

Do not let product enter drains.

# 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: liquid |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | 5.0 - 8.0 at 25 °C (77 °F) |
| e) | Melting point/freezing point | No data available |
| f) | Initial boiling point and boiling range | No data available |

| | | |
|---|---|---|
| g) | Partition coefficient: n-octanol/water | No data available |
| h) | Auto-ignition temperature | No data available |
| i) | Decomposition temperature | No data available |

| | | |
|---|---|---|
| j) | Viscosity | No data available |
| k) | Explosive properties | No data available |
| l) | Oxidizing properties | No data available |

### 9.2 Other safety information

No data available

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

No data available

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Hazardous decomposition products formed under fire conditions. - Carbon oxides
Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

No data available

Inhalation: No data available

Dermal: No data available

No data available

### Skin corrosion/irritation

No data available

### Serious eye damage/eye irritation

No data available

### Respiratory or skin sensitisation

No data available

### Germ cell mutagenicity

No data available

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

### Reproductive toxicity

No data available
No data available

### Specific target organ toxicity - single exposure

No data available

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**
No data available

### 12.2 Persistence and degradability

No data available

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

No data available

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Product**
Offer surplus and non-recyclable solutions to a licensed disposal company.

### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**
Not dangerous goods

### IMDG

Not dangerous goods

### IATA

Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**

No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards

No SARA Hazards

### Massachusetts Right To Know Components

No components are subject to the Massachusetts Right to Know Act.

### Pennsylvania Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Water | 7732-18-5 | |
| Glucose | 50-99-7 | |

### New Jersey Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Water | 7732-18-5 | |

| | |
|---|---|
| Glucose | 50-99-7 |

### California Prop. 65 Components

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

### HMIS Rating

| | |
|---|---|
| Health hazard: | 0 |
| Chronic Health Hazard: | |
| Flammability: | 0 |
| Physical Hazard | 0 |

### NFPA Rating

| | |
|---|---|
| Health hazard: | 0 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

### Further information


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 5.3 Revision Date: 04/06/2016 Print Date: 03/18/2017

**SIGMA-ALDRICH** *sigma-aldrich.com*

# SAFETY DATA SHEET

Version
5.5 Revision Date
01/15/2015 Print Date
03/18/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

| | | |
|---|---|---|
| Product name | : | L-(+)-Lactic acid |
| Product Number | : | L1750 |
| Brand | : | Sigma |
| CAS-No. | : | 79-33-4 |

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

| | | |
|---|---|---|
| Identified uses | : | Laboratory chemicals, Manufacture of substances |

### 1.3 Details of the supplier of the safety data sheet

| | | |
|---|---|---|
| Company | : | Sigma-Aldrich<br>3050 Spruce<br>Street<br>SAINT LOUIS MO 63103<br>USA |
| Telephone | : | +1 800-325-5832 |
| Fax | : | +1 800-325-5052 |

### 1.4 Emergency telephone number

| | | |
|---|---|---|
| Emergency Phone # | : | +1-703-527-3887 (CHEMTREC) |

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

**GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**
Skin irritation (Category 2), H315
Serious eye damage (Category 1),
H318

For the full text of the H-Statements mentioned in this Section, see Section 16.

### 2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)

| | |
|---|---|
| H315 | Causes skin irritation. |
| H318 | Causes serious eye damage. |

Precautionary statement(s)

| | |
|---|---|
| P264 | Wash skin thoroughly after handling. |
| P280 | Wear eye protection/ face protection. |
| P280 | Wear protective gloves. |

| | |
|---|---|
| P302 + P352 | IF ON SKIN: Wash with plenty of soap and water. |
| P305 + P351 + P338 + P310 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/ physician. |
| P332 + P313 | If skin irritation occurs: Get medical advice/ attention. |
| P362 | Take off contaminated clothing and wash before reuse. |

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

Synonyms : (S)-2-Hydroxypropionic acid Sarcolactic acid

Formula : $C_3H_6O_3$

Molecular weight : 90.08 g/mol

CAS-No. : 79-33-4

EC-No. : 201-196-2

**Hazardous components**

| Component | Classification | Concentration |
|---|---|---|
| **L-(+)-Lactic acid** | | |
| | Skin Irrit. 2; Eye Dam. 1; H315, H318 | <= 100 % |

For the full text of the H-Statements mentioned in this Section, see Section 16.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures**

**General advice**

Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

### If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

### In case of skin contact

Wash off with soap and plenty of water. Consult a physician.

### In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

### If swallowed

Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed

No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture

Carbon oxides

### 5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary.

## 5.4 Further information

No data available

# 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**

Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.
For personal protection see section 8.

## 6.2 Environmental precautions

Do not let product enter drains.

## 6.3 Methods and materials for containment and cleaning up

Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

## 6.4 Reference to other sections

For disposal see section 13.

# 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**

Avoid contact with skin and eyes. Avoid formation of dust and aerosols.Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

## 7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place.

Recommended storage temperature 2 - 8 °C

hygroscopic
Storage class (TRGS 510): Non Combustible Solids

## 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

# 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**
Contains no substances with occupational exposure limit values.

## 8.2 Exposure controls

**Appropriate engineering controls**
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

### Personal protective equipment Eye/face protection

Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact

Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374

If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Do not let product enter drains.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: solid |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | 1.2 |
| e) | Melting point/freezing point | Melting point/range: 53 °C (127 °F) |
| f) | Initial boiling point and boiling range | No data available |
| g) | Flash point | 110.00 °C (230.00 °F) - closed cup |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | No data available |
| j) | Upper/lower flammability or explosive limits | No data available |
| k) | Vapour pressure | No data available |
| l) | Vapour density | No data available |
| m) | Relative density | 1.200 g/cm3 |
| n) | Water solubility | No data available |

o) Viscosity — No data available

p) Explosive properties — No data available

q) Oxidizing properties — No data available

## 9.2 Other safety information

No data available

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

Avoid moisture.

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

LD50 Oral - Rat - female - 3,543 mg/kg

LC50 Inhalation - Rat - male and female - 4 h - > 7.94 mg/l
(OECD Test Guideline 403)

LD50 Dermal - Rabbit - male and female - > 2,000 mg/kg

No data available

### Skin corrosion/irritation

Skin - Rabbit
Result: Irritating to skin. - 24 h

### Serious eye damage/eye irritation

No data available

### Respiratory or skin sensitisation

Buehler Test - Guinea pig
Result: Does not cause skin sensitisation.

### Germ cell mutagenicity

Hamster
ovary
Cytogenetic analysis

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

| | |
|---|---|
| NTP: | No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP. |
| OSHA: | No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA. |

### Reproductive toxicity

No data available

Reproductive toxicity - Mouse - Oral
Maternal Effects: Other effects. Specific Developmental Abnormalities: Musculoskeletal system.

No data available

### Specific target organ toxicity - single exposure

No data available

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: OD2800000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

| | |
|---|---|
| Toxicity to fish | static test LC50 - Oncorhynchus mykiss (rainbow trout) - 130 mg/l - 96 h |
| Toxicity to daphnia and other aquatic invertebrates | static test EC50 - Daphnia magna (Water flea) - 130 mg/l - 48 h (OECD Test Guideline 202) |

| | |
|---|---|
| Toxicity to algae | static test EC50 - Pseudokirchneriella subcapitata (algae) - > 2.8 g/l - 72 h (OECD Test Guideline 201) |
| Toxicity to bacteria | Respiration inhibition EC50 - Sludge Treatment - > 100 mg/l - 3 h (OECD Test Guideline 209) |

### 12.2 Persistence and degradability

| | |
|---|---|
| Biodegradability | aerobic - Exposure time 20 d<br>Result: 67 % - Readily biodegradable<br>Remarks: The 10 day time window criterion is not fulfilled. |

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

No data available

## 13. DISPOSAL CONSIDERATIONS

### 13.1 Waste treatment methods

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

Not dangerous goods

### IMDG

Not dangerous goods

### IATA

Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**

No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards

Acute Health Hazard

### Massachusetts Right To Know Components

No components are subject to the Massachusetts Right to Know Act.

### Pennsylvania Right To Know Components

L-(+)-Lactic acid

## New Jersey Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| L-(+)-Lactic acid | 79-33-4 | |

## California Prop. 65 Components

| | CAS-No. | Revision Date |
|---|---|---|
| | 79-33-4 | |

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**Full text of H-Statements referred to under sections 2 and 3.**

| | |
|---|---|
| Eye Dam. | Serious eye damage |
| H315 | Causes skin irritation. |
| H318 | Causes serious eye damage. |
| Skin Irrit. | Skin irritation |

### HMIS Rating

| | |
|---|---|
| Health hazard: | 2 |
| Chronic Health Hazard: | |
| Flammability: | 1 |
| Physical Hazard | 0 |

**NFPA Rating**

| | |
|---|---|
| Health hazard: | 2 |
| Fire Hazard: | 1 |
| Reactivity Hazard: | 0 |

**Further information**


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the
product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas
Region 1-800-521-895

**SIGMA-ALDRICH** *sigma-aldrich.com*

# SAFETY DATA SHEET

Version
3.7 Revision Date
06/25/2014 Print Date
02/21/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

| | | |
|---|---|---|
| Product name | : | Sodium citrate dihydrate |
| Product Number | : | W302600 |
| Brand | : | Aldrich |
| CAS-No. | : | 6132-04-3 |

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

| | | |
|---|---|---|
| Identified uses | : | Laboratory chemicals, Manufacture of substances |

### 1.3 Details of the supplier of the safety data sheet

| | | |
|---|---|---|
| Company | : | Sigma-Aldrich<br>3050 Spruce<br>Street<br>SAINT LOUIS MO 63103<br>USA |
| Telephone | : | +1 800-325-5832 |
| Fax | : | +1 800-325-5052 |

### 1.4 Emergency telephone number

| | | |
|---|---|---|
| Emergency Phone # | : | +1-703-527-3887 (CHEMTREC) |

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

Not a hazardous substance or mixture.

### 2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

| | | |
|---|---|---|
| Synonyms | : | Sodium citrate tribasicdihydrate<br>Trisodium citratedihydrate<br>Citric acidtrisodium saltdihydrate |
| Formula | : | $C_6H_5Na_3O_7$ Â· $2H_2O$ |
| Molecular Weight | : | 294.1 g/mol |
| CAS-No. | : | 6132-04-3 |
| EC-No. | : | 200-675-3 |

No ingredients are hazardous according to OSHA criteria.
No components need to be disclosed according to the applicable regulations.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures If**

**inhaled**
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

### In case of skin contact

Wash off with soap and plenty of water.

### In case of eye contact

Flush eyes with water as a precaution.

### If swallowed

Never give anything by mouth to an unconscious person. Rinse mouth with water.

### 4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed

no data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture
Carbon oxides, Sodium oxides

### 5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

### 5.4 Further information
no data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

### 6.2 Environmental precautions
Do not let product enter drains.

### 6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections
For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities
Keep container tightly closed in a dry and well-ventilated place.

Keep in a dry place.

### 7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**
Contains no substances with occupational exposure limit values.

### 8.2 Exposure controls

**Appropriate engineering controls**
General industrial hygiene practice.

#### Personal protective equipment

**Eye/face protection**
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Do not let product enter drains.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

no data available

explosive limits

| | | |
|---|---|---|
| e) | Vapour pressure | no data available |
| f) | Vapour density | no data available |
| g) | Relative density | no data available |
| h) | Water solubility | 29.4 g/l at 20 °C (68 °F) - completely soluble |
| i) | Partition coefficient: n-octanol/water | no data available |
| j) | Auto-ignition temperature | no data available |
| k) | Decomposition temperature | no data available |

l) Viscosity no data available

m) Explosive properties no data available

n) Oxidizing properties no data available

## 9.1 Other safety information

no data available

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

no data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

no data available

### 10.4 Conditions to avoid

no data available

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - no data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

no data available

Inhalation: no data available

Dermal: no data available

no data available

### Skin corrosion/irritation

no data available

### Serious eye damage/eye irritation

no data available

### Respiratory or skin sensitisation

no data available

### Germ cell mutagenicity

no data available

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

## Reproductive toxicity

no data available

no data available

## Specific target organ toxicity - single exposure

no data available

## Specific target organ toxicity - repeated exposure

no data available

## Aspiration hazard

no data available

## Additional Information

RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

no data available

### 12.2 Persistence and degradability

no data available

### 12.3 Bioaccumulative potential

no data available

### 12.4 Mobility in soil

no data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

no data available

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company.

## Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

Not dangerous goods

### IMDG

Not dangerous goods

### IATA

Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**

SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components

SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards

No SARA Hazards

### Massachusetts Right To Know Components

No components are subject to the Massachusetts Right to Know Act.

### Pennsylvania Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Trisodium citrate | 6132-04-3 | |

### New Jersey Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Trisodium citrate | 6132-04-3 | |

### California Prop. 65 Components

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**HMIS Rating**

| | |
|---|---|
| Health hazard: | 0 |
| Chronic Health Hazard: | |
| Flammability: | 0 |
| Physical Hazard | 0 |

### NFPA Rating

| | |
|---|---|
| Health hazard: | 0 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

### Further information


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region

# SAFETY DATA SHEET

Version
5.12 Revision Date
09/23/2016 Print Date
03/18/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

Product name : Sulfuric acid

Product Number : 339741
Brand : Aldrich
Index-No. : 016-020-00-8

CAS-No. : 7664-93-9

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Synthesis of substances

### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce
Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

**GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**
Corrosive to metals (Category 1), H290
Skin corrosion (Category 1A), H314
Serious eye damage (Category 1),
H318

For the full text of the H-Statements mentioned in this Section, see Section 16.

### 2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word Danger

Hazard statement(s)
H290 May be corrosive to metals.
H314 Causes severe skin burns and eye damage.

| | |
|---|---|
| Precautionary statement(s) | |
| P234 | Keep only in original container. |
| P264 | Wash skin thoroughly after handling. |
| P280 | Wear protective gloves/ protective clothing/ eye protection/ face protection. |
| P301 + P330 + P331 | IF SWALLOWED: Rinse mouth. Do NOT induce vomiting. |
| P303 + P361 + P353 | IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower. |
| P304 + P340 + P310 | IF INHALED: Remove person to fresh air and keep comfortable for breathing. Immediately call a POISON CENTER/doctor. |
| P305 + P351 + P338 + P310 | IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER/doctor. |
| P363 | Wash contaminated clothing before reuse. |
| P390 | Absorb spillage to prevent material damage. |
| P405 | Store locked up. |
| P406 | Store in corrosive resistant stainless steel container with a resistant inner liner. |
| P501 | Dispose of contents/ container to an approved waste disposal plant. |

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

### 3.1 Substances

| | | |
|---|---|---|
| Formula | : | $H_2O_4S$ |
| Molecular weight | : | 98.08 g/mol |
| CAS-No. | : | 7664-93-9 |
| EC-No. | : | 231-639-5 |
| Index-No. | : | 016-020-00-8 |
| Registration number | : | 01-2119458838-20-XXXX |

**Hazardous components**

| Component | Classification | Concentration |
|---|---|---|
| **Sulfuric acid** | | |
| | Met. Corr. 1; Skin Corr. 1A; Eye Dam. 1; H290, H314 | <= 100 % |

For the full text of the H-Statements mentioned in this Section, see Section 16.

## 4. FIRST AID MEASURES

### 4.1 Description of first aid measures

**General advice**

Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

#### If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

#### In case of skin contact

Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Consult a physician.

#### In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.Continue rinsing eyes during transport to hospital.

#### If swallowed

Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed

No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture

No data available

### 5.3 Advice for firefighters

Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information

No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**

Wear respiratory protection. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.

For personal protection see section 8.

### 6.2 Environmental precautions

Do not let product enter drains.

### 6.3 Methods and materials for containment and cleaning up

Soak up with inert absorbent material and dispose of as hazardous waste. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections

For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**

Avoid inhalation of vapour or mist.

For precautions see section 2.2.

### 7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

### 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**

| Component | CAS-No. | Value | Control parameters | Basis |
|---|---|---|---|---|
| Sulfuric acid | 7664-93-9 | TWA | 0.2 mg/m3 | USA. ACGIH Threshold Limit Values (TLV) |
| | | TWA | 1 mg/m3 | USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000 |

| | | | | |
|---|---|---|---|---|
| | | TWA | 1 mg/m3 | USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants |

**Derived No Effect Level (DNEL)**

| Application Area | Exposure routes | Health effect | Value |
|---|---|---|---|
| Workers | Inhalation | Acute local effects | 0.1 mg/m3 |
| Workers | Inhalation | Long-term local effects | 0.05 mg/m3 |

**Predicted No Effect Concentration (PNEC)**

| Compartment | Value |
|---|---|
| Marine water | 0.00025 mg/l |
| Fresh water | 0.0025 mg/l |
| Marine sediment | 0.002 mg/kg |
| Fresh water sediment | 0.002 mg/kg |
| Onsite sewage treatment plant | 8.8 mg/l |

## 8.2 Exposure controls

**Appropriate engineering controls**
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

### Personal protective equipment Eye/face protection

Tightly fitting safety goggles. Faceshield (8-inch minimum). Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Fluorinated rubber
Minimum layer thickness: 0.7 mm
Break through time: 480 min
Material tested:Vitoject® (KCL 890 / Aldrich Z677698, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.2 mm
Break through time: 30 min
Material tested:Dermatril® P (KCL 743 / Aldrich Z677388, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### Body Protection

Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Do not let product enter drains.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: clear, liquid |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |
| d) | pH | 1.2 at 5 g/l |
| e) | Melting point/freezing point | 3 °C (37 °F) |
| f) | Initial boiling point and boiling range | 290 °C (554 °F) - lit. |

| | | |
|---|---|---|
| g) | Flash point | Not applicable |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | No data available |
| j) | pper/lower flammability or explosive limits | No data available |
| k) | Vapour pressure | 1.33 hPa (1.00 mmHg) at 145.8 °C (294.4 °F) |
| l) | Vapour density | 3.39 - (Air = 1.0) |
| m) | Relative density | 1.84 g/cm3 at 25 °C (77 °F) |
| n) | Water solubility | soluble |
| o) | Partition coefficient: n-octanol/water | No data available |
| p) | Auto-ignition temperature | No data available |
| q) | Decomposition temperature | No data available |

r) Viscosity No data available

s) Explosive properties No data available

t) Oxidizing properties No data available

## 9.2 Other safety information

| | |
|---|---|
| Surface tension | 55.1 mN/m at 20 °C (68 °F) |
| Relative vapour density | 3.39 - (Air = 1.0) |

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

No data available

### 10.5 Incompatible materials

Bases, Halides, Organic materials, Carbides, fulminates, Nitrates, picrates, Cyanides, Chlorates, alkali halides, Zinc salts, permanganates, e.g. potassium permanganate, Hydrogen peroxide, Azides, Perchlorates., Nitromethane, phosphorous, Reacts violently with:, cyclopentadiene, cyclopentanone oxime, nitroaryl amines, hexalithium disilicide, phosphorous(III) oxide, Powdered metals

### 10.6 Hazardous decomposition products

Hazardous decomposition products formed under fire conditions. - Sulphur oxides
Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**

LD50 Oral - Rat - 2,140 mg/kg

LC50 Inhalation - Rat - 2 h - 510 mg/m3

Dermal: No data available

No data available

### Skin corrosion/irritation

Skin - Rabbit
Result: Extremely corrosive and destructive to tissue.

### Serious eye damage/eye irritation

Eyes - Rabbit
Result: Corrosive to eyes

### Respiratory or skin sensitisation

No data available

### Germ cell mutagenicity

No data available

### Carcinogenicity

The International Agency for Research on Cancer (IARC) has determined that occupational exposure to strong-inorganic-acid mists containing sulfuric acid is carcinogenic to humans (group 1).

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

### Reproductive toxicity

No data available

### Specific target organ toxicity - single exposure

No data available

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: WS5600000

Material is extremely destructive to tissue of the mucous membranes and upper respiratory tract, eyes, and skin., spasm, inflammation and edema of the larynx, spasm, inflammation and edema of the bronchi, pneumonitis, pulmonary edema, burning sensation, Cough, wheezing, laryngitis, Shortness of breath, Headache, Nausea, Vomiting, Pulmonary edema. Effects may be delayed., To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Stomach - Irregularities - Based on Human Evidence
Stomach - Irregularities - Based on Human Evidence

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

| | |
|---|---|
| Toxicity to fish | LC50 - Gambusia affinis (Mosquito fish) - 42 mg/l - 96 h |
| Toxicity to daphnia and other aquatic invertebrates | EC50 - Daphnia magna (Water flea) - 29 mg/l - 24 h |

### 12.2 Persistence and degradability

The methods for determining the biological degradability are not applicable to inorganic substances.

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

## 13. DISPOSAL CONSIDERATIONS

### 13.1 Waste treatment methods

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

UN number: 1830 Class: 8 Packing group: II
Proper shipping name: Sulfuric acid
Reportable Quantity (RQ): 1000 lbs

Poison Inhalation Hazard: No

### IMDG

UN number: 1830 Class: 8 Packing group: II EMS-No: F-A, S-B
Proper shipping name: SULPHURIC ACID

### IATA

UN number: 1830 Class: 8 Packing group: II
Proper shipping name: Sulphuric acid

## 15. REGULATORY INFORMATION

**SARA 302 Components**

The following components are subject to reporting levels established by SARA Title III, Section 302:

| | CAS-No. | Revision Date |
|---|---|---|
| Sulfuric acid | 7664-93-9 | 2007-07-01 |

### SARA 313 Components

The following components are subject to reporting levels established by SARA Title III, Section 313:

| | CAS-No. | Revision Date |
|---|---|---|
| Sulfuric acid | 7664-93-9 | 2007-07-01 |

**SARA 311/312 Hazards**

Acute Health Hazard, Chronic Health Hazard

**Massachusetts Right To Know Components**

| | CAS-No. | Revision Date |
|---|---|---|
| Sulfuric acid | 7664-93-9 | 2007-07-01 |

**Pennsylvania Right To Know Components**

| | CAS-No. | Revision Date |
|---|---|---|
| Sulfuric acid | 7664-93-9 | 2007-07-01 |

**New Jersey Right To Know Components**

| | CAS-No. | Revision Date |
|---|---|---|
| Sulfuric acid | 7664-93-9 | 2007-07-01 |

**California Prop. 65 Components**

| | CAS-No. | Revision Date |
|---|---|---|
| WARNING! This product contains a chemical known to the State of California to cause cancer. | 7664-93-9 | 2007-09-28 |

Sulfuric acid

## 16. OTHER INFORMATION

**Full text of H-Statements referred to under sections 2 and 3.**

| | |
|---|---|
| Eye Dam. | Serious eye damage |
| H290 | May be corrosive to metals. |
| H314 | Causes severe skin burns and eye damage. |
| H318 | Causes serious eye damage. |
| Met. Corr. | Corrosive to metals |

### HMIS Rating

| | |
|---|---|
| Health hazard: | 3 |
| Chronic Health Hazard: | * |
| Flammability: | 0 |
| Physical Hazard | 0 |

**NFPA Rating**

| | |
|---|---|
| Health hazard: | 3 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

**Further information**


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 5.12 Revision Date: 09/23/2016 Print Date: 03/18/2017

# SAFETY DATA SHEET

Version
3.5 Revision Date
04/28/2015 Print Date
02/21/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

| | | |
|---|---|---|
| Product name | : | Xylitol |
| Product Number | : | X3375 |
| Brand | : | Sigma |
| CAS-No. | : | 87-99-0 |

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

| | | |
|---|---|---|
| Identified uses | : | Laboratory chemicals, Manufacture of substances |

### 1.3 Details of the supplier of the safety data sheet

| | | |
|---|---|---|
| Company | : | Sigma-Aldrich<br>3050 Spruce<br>Street<br>SAINT LOUIS MO 63103<br>USA |
| Telephone | : | +1 800-325-5832 |
| Fax | : | +1 800-325-5052 |

### 1.4 Emergency telephone number

| | | |
|---|---|---|
| Emergency Phone # | : | +1-703-527-3887 (CHEMTREC) |

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

Not a hazardous substance or mixture.

### 2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

| | | |
|---|---|---|
| Synonyms | : | Xylite |
| Formula | : | $C_5H_{12}O_5$ |
| Molecular weight | : | 152.15 g/mol |
| CAS-No. | : | 87-99-0 |
| EC-No. | : | 201-788-0 |

No components need to be disclosed according to the applicable regulations.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures If**

**inhaled**
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

### In case of skin contact
Wash off with soap and plenty of water.

### In case of eye contact
Flush eyes with water as a precaution.

### If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed
No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture
Carbon oxides

### 5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information
No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

### 6.2 Environmental precautions
No special environmental precautions required.

### 6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections
For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**
Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

**7.2 Conditions for safe storage, including any incompatibilities** Keep container tightly closed in a dry and well-ventilated place. Storage class (TRGS 510): Non Combustible Solids

### 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

### 8.1 Control parameters

**Components with workplace control parameters**
Contains no substances with occupational exposure limit values.

### 8.2 Exposure controls

**Appropriate engineering controls**
General industrial hygiene practice.

#### Personal protective equipment

**Eye/face protection**
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

#### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

#### Body Protection

Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

#### Respiratory protection

Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

#### Control of environmental exposure

No special environmental precautions required.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

### 9.1 Information on basic physical and chemical properties

a) Appearance — Form: crystalline
Colour: colourless

b) Odour No data available

c) Odour Threshold No data available

d) pH No data available

e) Melting point/freezing point Melting point/range: 94 - 97 °C (201 - 207 °F)

f) Initial boiling point and boiling range No data available

g) Flash point No data available

h) Evaporation rate No data available

i) Flammability (solid, gas) No data available

j) Upper/lower flammability or No data available explosive limits

| | | |
|---|---|---|
| k) | Vapour pressure | No data available |
| l) | Vapour density | No data available |
| m) | Relative density | No data available |
| n) | Water solubility | No data available |
| o) | Partition coefficient: n-octanol/water | No data available |
| p) | Auto-ignition temperature | No data available |
| q) | Decomposition temperature | No data available |

r) Viscosity No data available

s) Explosive properties No data available

t) Oxidizing properties No data available

### 9.2 Other safety information

No data available

## 10. STABILITY AND REACTIVITY

**10.1 Reactivity**

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

No data available

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

**11.1 Information on toxicological effects**

**Acute toxicity**
LD50 Oral - Rat - 16,500 mg/kg

Inhalation: No data available

Dermal: No data available

No data available

### Skin corrosion/irritation

No data available

### Serious eye damage/eye irritation

No data available

### Respiratory or skin sensitisation

No data available

### Germ cell mutagenicity

No data available

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

### Reproductive toxicity

No data available

No data available

### Specific target organ toxicity - single exposure

No data available

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

No data available

### 12.2 Persistence and degradability

No data available

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

No data available

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company.

### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**

Not dangerous goods

### IMDG

Not dangerous goods

IATA
Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components

This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards

No SARA Hazards

### Massachusetts Right To Know Components

No components are subject to the Massachusetts Right to Know Act.

### Pennsylvania Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Xylitol | 87-99-0 | |

### New Jersey Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Xylitol | 87-99-0 | |

### California Prop. 65 Components

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**HMIS Rating**

| | |
|---|---|
| Health hazard: | 0 |
| Chronic Health Hazard: | |
| Flammability: | 0 |
| Physical Hazard | 0 |

### NFPA Rating

| | |
|---|---|
| Health hazard: | 0 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

### Further information


The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region

# SAFETY DATA SHEET

Version
4.5 Revision Date
07/15/2015 Print Date
03/18/2017

## 1. PRODUCT AND COMPANY IDENTIFICATION

**1.1 Product identifiers**

| | | |
|---|---|---|
| Product name | : | D-(+)-Xylose |
| Product Number | : | X1500 |
| Brand | : | Sigma-Aldrich |
| CAS-No. | : | 58-86-6 |

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich
3050 Spruce
Street
SAINT LOUIS MO 63103
USA

Telephone : +1 800-325-5832
Fax : +1 800-325-5052

### 1.4 Emergency telephone number

Emergency Phone # : +1-703-527-3887 (CHEMTREC)

## 2. HAZARDS IDENTIFICATION

**2.1 Classification of the substance or mixture**

Not a hazardous substance or mixture.

### 2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

**3.1 Substances**

| | | |
|---|---|---|
| Formula | : | $C_5H_{10}O_5$ |
| Molecular weight | : | 150.13 g/mol |
| CAS-No. | : | 58-86-6 |
| EC-No. | : | 200-400-7 |

No components need to be disclosed according to the applicable regulations.

## 4. FIRST AID MEASURES

**4.1 Description of first aid measures If**

**inhaled**
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

### In case of skin contact
Wash off with soap and plenty of water.

### In case of eye contact
Flush eyes with water as a precaution.

### If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

### 4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed
No data available

## 5. FIREFIGHTING MEASURES

**5.1 Extinguishing media Suitable**

**extinguishing media**
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

### 5.2 Special hazards arising from the substance or mixture
Carbon oxides

### 5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

### 5.4 Further information
No data available

## 6. ACCIDENTAL RELEASE MEASURES

**6.1 Personal precautions, protective equipment and emergency procedures**
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

### 6.2 Environmental precautions
No special environmental precautions required.

### 6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

### 6.4 Reference to other sections
For disposal see section 13.

## 7. HANDLING AND STORAGE

**7.1 Precautions for safe handling**
Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

**7.2 Conditions for safe storage, including any incompatibilities** Keep container tightly closed in a dry and well-ventilated place. Storage class (TRGS 510): Non Combustible Solids

### 7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

**8.1 Control parameters**

**Components with workplace control parameters**
Contains no substances with occupational exposure limit values.

### 8.2 Exposure controls

**Appropriate engineering controls**
General industrial hygiene practice.

### Personal protective equipment

**Eye/face protection**
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

#### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

#### Body Protection

Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

#### Respiratory protection

Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

#### Control of environmental exposure

No special environmental precautions required.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**9.1 Information on basic physical and chemical properties**

| | | |
|---|---|---|
| a) | Appearance | Form: crystalline<br>Colour: white |
| b) | Odour | No data available |
| c) | Odour Threshold | No data available |

| | | |
|---|---|---|
| d) | pH | 4.5 - 6.0 |
| e) | Melting point/freezing point | Melting point/range: 154 - 158 °C (309 - 316 °F) |
| f) | Initial boiling point and boiling range | No data available |
| g) | Flash point | No data available |
| h) | Evaporation rate | No data available |
| i) | Flammability (solid, gas) | The product is not flammable. - Flammability (solids |

No data available

explosive limits

| | | |
|---|---|---|
| j) | Vapour pressure | No data available |
| k) | Vapour density | No data available |
| l) | Relative density | 1.525 g/cm3 |
| m) | Water solubility | 150.13 g/l at 20 °C (68 °F) |
| n) | Partition coefficient: n-octanol/water | No data available |
| o) | Auto-ignition temperature | No data available |
| p) | Decomposition temperature | No data available |

q) Viscosity — No data available

r) Explosive properties — No data available

s) Oxidizing properties — No data available

### 9.2 Other safety information

No data available

## 10. STABILITY AND REACTIVITY

### 10.1 Reactivity

No data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

No data available

### 10.4 Conditions to avoid

No data available

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - No data available
In the event of fire: see section 5

## 11. TOXICOLOGICAL INFORMATION

### 11.1 Information on toxicological effects

**Acute toxicity**

LD50 Oral - Rat - male - > 2,200 mg/kg

LD50 Oral - Rat - female - > 2,500 mg/kg

Inhalation: No data available

Dermal: No data available

LD50 Oral - Rat - males - 2,214 mg/kg

LD50 Oral - Rat - female - 2,513 mg/kg

### Skin corrosion/irritation

No data available

### Serious eye damage/eye irritation

No data available

### Respiratory or skin sensitisation

No data available

### Germ cell mutagenicity

No data available

### Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

### Reproductive toxicity

No data available

No data available

### Specific target organ toxicity - single exposure

No data available

### Specific target organ toxicity - repeated exposure

No data available

### Aspiration hazard

No data available

### Additional Information

RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

## 12. ECOLOGICAL INFORMATION

**12.1 Toxicity**

No data available

### 12.2 Persistence and degradability

Biodegradability aerobic - Exposure time 15 d
Result: 62.9 % - Readily biodegradable

### 12.3 Bioaccumulative potential

No data available

### 12.4 Mobility in soil

No data available

### 12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

### 12.6 Other adverse effects

No data available

## 13. DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods**

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company.

### Contaminated packaging

Dispose of as unused product.

## 14. TRANSPORT INFORMATION

**DOT (US)**
Not dangerous goods

### IMDG
Not dangerous goods

### IATA
Not dangerous goods

## 15. REGULATORY INFORMATION

**SARA 302 Components**
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

### SARA 313 Components
This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

### SARA 311/312 Hazards
No SARA Hazards

### Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

### Pennsylvania Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Xylose | 58-86-6 | |

### New Jersey Right To Know Components

| | CAS-No. | Revision Date |
|---|---|---|
| Xylose | 58-86-6 | |

### California Prop. 65 Components

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

## 16. OTHER INFORMATION

**HMIS Rating**

| | |
|---|---|
| Health hazard: | 0 |
| Chronic Health | |
| Hazard: Flammability: | 0 |
| Physical Hazard | 0 |

### NFPA Rating

| | |
|---|---|
| Health hazard: | 0 |
| Fire Hazard: | 0 |
| Reactivity Hazard: | 0 |

### Further information

 The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

### Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas
Region 1-800-521-8956

Version: 4.5 Revision Date: 07/15/2015 Print Date: 03/18/2017

# Safety data sheet

## FUTERRO POLYLACTIQUE ACIDE

**WARNING :**

**FOR STACKING**

**PALLETS, SEE**

**SECTION 7**

### 1. Identification of the substance / preparation and of the company / undertaking

| | |
|---|---|
| Trade name | FUTERRO POLYLACTIQUE ACIDE |
| SDS number | PRUB-PLA01 |
| Chemical name | Polylactique acide |
| **MATERIAL USE** | raw material , polymer |
| **RESPONSIBLE FOR PLACING ON THE MARKET** | |
| Trade name of the firm | see below this page.<br>Email address: Petrochemicals.felr-sds@total.com ( Safety data sheet ) |
| **EMERGENCY NUMBER** | FUTERRO : + 32 (0)69 45 22 76<br>info@futerro.com |
| Official advisory body | The UK National Poisons Emergency number is 0870 600 6266 (Outside the UK: +44 870 600 6266)<br>NB: these services are only available to health professionals IRL:<br>The National Poisons Information Centre<br>PO Box 1297, Beaumont Hospital, Beaumont Road<br>Dublin 9.<br>Telephone: +353 (01) 837 9966 / +353 (01) 809 2568 |

## 2. Hazards identification

| | |
|---|---|
| Main hazards | none to our knowledge |
| | low risk for temperatures below 150 °C |
| | Symptoms related to use |
| Inhalation | fine dust may cause irritation of respiratory system and mucous. |
| | if heated to more than 150°C, the product may form vapours or fumes which may cause irritation of respiratory tract and cause coughing and sensation of shortness of breath. |
| Skin contact | may be irritating |
| | in contact with hot material, may cause severe thermal burns |
| Eye contact | fine dust may cause irritation to ocular mucous. |
| Ingestion | in case of ingestion of small quantities, no important effect observed. in case of ingestion of larger amounts: abdominal pain, diarrhoea, ... |
| Adverse environmental effects | the product is inherently biodegradable |
| Adverse physicochemical effects | combustible if exposed to flames. |
| | flowing product can create electrical charge, resulting sparks may ignite dust or cause an explosion in some concentration ranges. |

## 3. Composition / information on ingredients

| | |
|---|---|
| chemical name | Polylactique acide |

# Safety data sheet

| FUTERRO POLYLACTIQUE ACIDE | |
|---|---|
| Concentration (%) | > 98 % |
| CAS number | CAS: 9051-89-2 |
| EINECS or ELINCS number | the product is a polymer, following the European regulation, registration on the EINECS (European Inventory of Existing Commercial Chemical Substances) inventory is not required. |
| **Substances presenting a health hazard** | none to our knowledge |

## 4. First-aid measures

IN CASE OF HEAVY OR PERSISTENT DISTURBANCES, CALL A DOCTOR OR SEEK MEDICAL ADVICE URGENTLY

| | Route of exposure |
|---|---|
| Inhalation | exposure to spray, fumes and vapours produced by heated or burned product:<br>bring patient into fresh air<br>seek medical advice. |
| Skin contact | in case of irritation caused by fine dust: wash with copious volumes of water, until the irritation disappears.<br>exposure to splashing of hot product:<br>treat the affected part with cold water (by spraying or immersion).<br>no attempt should be made to detach molten product adhering to the skin or to remove clothing attached with molten material, the injured body part would risk being pulled out; usually the layer detaches itself after a few days.<br>in case of severe burns, seek hospital treatment |
| Eye contact | in case of irritation caused by fine dust: wash with copious volumes of water, until the irritation disappears.<br>Get medical advice (ophthalmologist)<br>exposure to splashing of hot product: treat the eyes with cold water.<br>in case of severe burns, seek hospital treatment |
| Ingestion | do not induce vomiting.<br>seek medical advice immediately. |

## 5. Fire - fighting measures

| | |
|---|---|
| Technical measures | stop the fire spreading.<br>call the fire brigade immediately.<br>evacuate non-essential personnel |
| | Extinguishing media |
| Suitable | for minor fires : carbon dioxide (CO2) or powder , water<br>for more extensive fires : foam. water spray (mist) to cool the surfaces exposed to the fire. |
| Not to be used | do not use water jets (stick jets) for extinguishing fire since they could help to spread the flames |
| Special exposure hazards | dust may form an explosive mixture with air, ignited by sparks or sources of ignition. |
| Special peril | complete combustion, with an excess of oxygen forms: carbon dioxide (CO2) and water vapour.<br>partial combustion, forms also: carbon monoxide (CO), soot and cracked products: aldehydes, ketones |

| | FUTERRO POLYLACTIQUE ACIDE |
|---|---|
| Protective equipment for firefighters | wear suitable breathing equipment, in case of risk of exposure to vapour or fumes. |

## 6. Accidental release measures

| | |
|---|---|
| refer to points 8 and 13 After spillage / leakage | |
| on soil | granules spilled on the floor can cause a risk of slipping on smooth surfaces. |
| | recover the spilled product by sweeping or suction; put it in containers to facilitate its disposal. |
| | dispose safely in accordance with local or national regulations. |
| on water | prevent the spilled material from spreading. |
| | the product has a density > 1000 kg/m³, it sinks in water. |
| | refer to a specialist for waste disposal in a safe manner in accordance with local or national regulations. |

## 7. Handling and storage

| | |
|---|---|
| **HANDLING** | |
| Technical measures | all pneumatic transport equipment must be electrically earthed. |
| | avoid dust accumulation by use of filters in the pneumatic transport equipment. |
| **STORAGE** | |
| Storage conditions | store at ambient temperature and at atmospheric pressure in original packaging (plastic or cardboard boxes) or in silo made of appropriate material (aluminium, stainless steel, ...). |
| | do not store near highly flammable materials. |
| | store away from heating source. avoid static electricity build up with connection to earth. |
| | store in dry, well-ventilated area. |
| | prolonged storage preferably out of the sun or other sources of radiation |
| Storage of pallets | two pallets may be stacked on flooring in sound condition. |
| | however, when the pictorial warning as shown on the top of the safety data sheet is affixed to the pallet, the pallet must never be placed either on top of or below another pallet. |
| | N.B. :here the term pallet includes both the pallet and its load. |
| | when pallets are stored in racks, it should be checked whether the pallet is fit for stacking in the concerned racks |
| Incompatible materials | avoid contact with strong oxidizing materials , water |
| **SPECIFIC USE(S)** | no information available |
| refer to point 8 | |

## 8. Exposure controls / personal protection

Exposure controls

## FUTERRO POLYLACTIQUE ACIDE

**OCCUPATIONAL EXPOSURE LIMIT** respirable dust particles:

US (ACGIH-2007): TLV- 8h TWA: 3 mg/m³
UK: HSE EH40/2005:
Long-term exposure limit (8-hour TWA reference period) : 4 mg/m³ (Respirable Dust)
IRL(2002): OEL (8h): 4 mg/m³ (respirable)
ZA (2006): OEL (8h): 5 mg/m³ (respirable particulate: PNOC)

inhalable dust particles:

US (ACGIH-2007): TLV-8h TWA: 10 mg/m³
UK: HSE EH40/2005:
Long-term exposure limit (8-hour TWA reference period) : 10 mg/m³ (Total Inhalable Dust)
IRL(2002): OEL (8h): 10 mg/m³ (total inhalable)
ZA (2006): OEL (8h): 10 mg/m³ (inhalable particulate: PNOC)

**EXPOSURE CONTROLS**

Occupational exposure controls Personal protection

Respiratory protection: in case of risk of overexposure to dust, vapour or fumes (during product processing), it is recommended that a local exhaust system is placed above the conversion equipment (a fume hood) and the working area must be properly ventilated.
wear a suitable anti-dust respirator
recommended filter type : P1

Skin and body protection: where exposure is likely, protective clothing must be worn including gloves Eye protection: goggles/spectacles

Other personal protection: safety non-slip shoes in areas where spills or leaks can occur.
shower and eye fountain available.

Industrial health measures: avoid contact with skin and eyes. do not store near food products.
remove all contaminated clothing and remove protective clothing when the work is completed.

Environmental exposure controls: unregulated

## 9. Physical and chemical properties

**GENERAL INFORMATION**

| | |
|---|---|
| Appearance | pellets from a diameter of 2 to 5 mm |
| Physical state at 20°C | solid |
| Colour | transparent , translucent , white opaque |
| Odour | odourless |

**IMPORTANT HEALTH, SAFETY AND ENVIRONMENTAL INFORMATION**

Change in physical state at 1013 hPa

| | | |
|---|---|---|
| Melting range | (°C) | from 150 to 180 |
| Softening point | (°C) | 55 to 65 |
| Flash point (ASTM D 1929)(°C) | | > 250 |
| Decomposition point | (°C) | > 220 |

Auto-ignition temperature (°C) > 250 Explosion limits (kg/m³)

| | |
|---|---|
| Lower | 0.015 ( for polymer dust < 63 µm ) |
| Vapour pressure at 20°C (hPa) | none |

# Safety data sheet

| | |
|---|---|
| | **FUTERRO POLYLACTIQUE ACIDE** |
| Density, mass at 20°C (kg/m³) | 1200 to 1300 |
| Solubility in water at 20°C (mg/l) | insoluble |
| pH value (concentrated product) | not applicable |
| Viscosity (mm²/s) | not applicable |
| **OTHER INFORMATION** | no information available |

## 10. Stability and reactivity

| | |
|---|---|
| Stability | stable under normal operating conditions of storage, handling and use |
| Hazardous reactions | dust may form an explosive mixture with air, ignited by sparks or sources of ignition. |
| **CONDITIONS TO AVOID** | avoid contact with strong oxidizing materials , water<br>avoid proximity or contact with flames or sparks<br>it is recommended not to heat at a temperature higher than 230 °C |
| **HAZARDOUS DECOMPOSITION PRODUCTS** | complete combustion, with an excess of oxygen forms: carbon dioxide ($CO_2$) and water vapour.<br>partial combustion, forms also: carbon monoxide (CO), soot and cracked products: aldehydes, ketones |
| Advice to prevent explosion | avoid dust accumulation by use of filters in the pneumatic transport equipment.<br>thoroughly ventilate the working place.<br>all conductive materials must be electrically earthed. |

## 11. Toxicological information

| | |
|---|---|
| **ACUTE TOXICITY** | |
| Ingestion | in case of ingestion of small quantities, no important effect observed. in case of ingestion of larger amounts: abdominal pain, diarrhoea, ... |
| **LOCAL EFFECT** | |
| Inhalation | dust may cause irritation of respiratory system.<br>if heated to more than 150°C, the product may form vapours or fumes which may cause irritation of respiratory tract and cause coughing and sensation of shortness of breath. |
| Skin contact | may be irritating<br>in contact with hot material, may cause severe thermal burns<br>thermal decomposition products are produced at elevated temperatures and these may be irritating |
| Eye contact | fine dust may cause irritation to ocular mucous.<br>splashing of molten droplets causes ocular tissue burns.<br>thermal decomposition products are produced at elevated temperatures and these may be irritating |
| **SENSITIZATION** | |
| Skin contact | following the available information, not regarded as a sensitiser |
| **SPECIFIC EFFECTS** | no particular preoccupation for man (According to available experimental data) |

## 12. Ecological information

| | |
|---|---|
| Information on ecological effects<br>**MOBILITY** | avoid losses to the environment whenever possible. |

# Safety data sheet

| | FUTERRO POLYLACTIQUE ACIDE |
|---|---|
| water / air | there is a slow loss by evaporation |
| soil and sediments | because of its physico-chemical properties, the product has a low soil mobility |
| **PERSISTENCE AND DEGRADABILITY** | |
| Biodegradation | the product is inherently biodegradable |
| **BIOACCUMULATIVE POTENTIAL** | potential bioaccumulation of the product in environment is very low |
| **ECOTOXICITY** | because of its structure, the product should not be dangerous for aquatic life |
| 72 hours-IC50-Algae (mg/l) | > 1100 mg/l |
| **13. Disposal considerations** | |
| Waste disposal | dispose in a safe manner in accordance with local/national regulations. authorized disposal<br>do not dispose off by means of sinks, drains or into the immediate environment |
| Disposal of contaminated packaging | dispose in a safe manner in accordance with local/national regulations. |
| **14. Transport information** | |
| **Road (ADR) / Rail (RID)** | Not restricted for transport. |
| UN Number | not applicable |
| **Marine (IMO)** | Not restricted for transport. |
| **Air transport (ICAO / IATA)** | Not restricted for transport. |
| **15. Regulatory information** | |
| Labelling and Classification EC | |
| Symbol(s) EC | Not classified according to EEC directives 67/548/EEC (dangerous substances) and 1999/45/EC (dangerous preparations). |
| **Germany** | |
| Wassergefährdungsklasse | NWG: non-hazardous to waters |
| Registration | the product is a polymer, following the European regulation, registration on the EINECS (European Inventory of Existing Commercial Chemical Substances) inventory is not required.<br>listed on the United States TSCA (Toxic Substances Control Act) inventory<br>listed on the Canadian DSL (Domestic Substances List) inventory.<br>listed on the Japanese ENCS (Existing & New Chemical Substances) inventory.<br>listed on the Korean ECL (Existing Chemical List) inventory.<br>listed on the People's Republic of China register: CRC-SEPA (Chemical Registration Center for Chinese State Environmental Protection Administration) |

## 16. Other information

| | |
|---|---|
| Training advice | The use of this product requires specific training.<br>The user must receive all product information in order to handle the product safely<br>(personal protection equipment and best practice standards) |
| Recommended uses | Restricted to professional users |

# Safety data sheet

| FUTERRO POLYLACTIQUE ACIDE | |
|---|---|
| Further information | no information available |

Revised : 25/02/2008 Supersedes : 25/02/2008

Safety data sheet conforms to the Regulation (EU) N° 1907/2006

# Safety data sheet

This information applies to the PRODUCT AS SUCH and conforming to specifications of FUTERRO. In case of formulations or mixtures, it is necessary to ascertain that a new danger will not appear.

The information contained is based on our knowledge of the product, at the date of publishing and it is given quite sincerely. However the revision of some data is in progress.

Users are advised of possible additional hazards when the product is used in applications for which it was not intended. This sheet shall only be used and reproduced for prevention and security purposes.

The references to legislative, regulatory and codes of practice documents cannot be considered as exhaustive.

It is the responsibility of the person receiving the product to refer to the totality of the official documents concerning the use, the possession and the handling of the product.

It is also the responsibility of the handlers of the product to pass on to any subsequent persons who will come into contact with the product. (usage, storage, cleaning of containers, other processes) the totality of the information contained within this safety data sheet and necessary for safety at work, the protection of health and the protection of environment.

The (*) indicate the changes made with respect to the previous version.

# FUTERRO POLY-LACTIDE

INJECTION GRADE / *Futerro ref.*

GENERAL PURPOSE POLYLATIC ACID / *product name*

# DESCRIPTION

Futerro® PLA injection grade is a thermoplastic resin derived from annually renewable resources and is specifically designed for injection molding applications where the requirements are clarity with heat deflection temperatures lower than 55ºC.

Futerro® PLA injection grade is easily processed on conventional injection equipment. The material is stable in the molten state, provided that the drying procedures are followed.

**PURITY (1)**

| | | |
|---|---|---|
| L-poly-Lactide content | % w/w | Min. 99 |
| Water content | ppm | Max. 250 |
| Free Lactide content | % w/w | Max. 0.4 |

**PHYSICAL PROPERTIES PLA POLYMER (1)**

| | | | |
|---|---|---|---|
| Specific Gravity @25°C | | 1.24 | ISO 1183 |
| Melt Density @230ºC | | 1.08-1.12 | |
| Melt Index @190ºC/2.16kg | g/10 min | 10 - 30 | ISO 1133 |
| Melt Index @210ºC/2.16kg | g/10 min | 30 - 60 | ISO 1133 |
| Haze (2 mm) | % | < 5 | ISO 14782 |
| Transmittance (2 mm) | % | > 90 | ISO 14782 |
| Glass Transition Temperature | °C | 52-60ºC | ISO 11357 |
| Crystalline Melt Temperature | °C | 145-175ºC | ISO 11357 |

**MECHANICAL PROPERTIES (1)**

| | | | |
|---|---|---|---|
| Tensile Strength @ Break | MPa | 55 | ISO 527 |
| Tensile Yield Strength | MPa | 60 | ISO 527 |
| Tensile Modulus | MPa | 3500 | ISO 527 |
| Tensile Elongation | % | 6.0 | ISO 527 |
| Notched Izod Impact | kJ/m² | 3.5 | ISO 180 |
| Flexural Yield Strength | MPa | 90 | ISO 178 |

(1) Typical properties; not to be construed as specifications.

# PROCESSING INFORMATION

**Machine Configuration**

Futerro® PLA can be processed on conventional injection molding equipment. The material is stable in the molten state, provided that the drying procedures are followed. Mold flow is highly dependent on melt temperature. It is recommended to balance screw speed, back pressure, and process temperature to control melt temperature. Injection speed should be medium to fast.

A general purpose screw designed to minimize residence time and shear works well..

# Startup and Shutdown

Futerro® PLA polymer is not compatible with a wide variety of commodity resins, and special purging sequences should be followed:

- 1. Clean machine and bring temperatures to steady state with low-viscosity, general-purpose polystyrene or polypropylene.
- 2. Vacuum out hopper system to avoid contamination.
- 3. Introduce PLA polymer into the machine at the operating conditions used in Step 1.
- 4. Once PLA polymer has purged, reduce barrel temperatures to desired set points.
- 5. At shutdown, purge machine with high-viscosity polystyrene or polypropylene.

# Drying

In-line drying may be required. A moisture content around 0.025% (250 ppm) is recommended to prevent viscosity degradation. For injection process, it is better to reach 0.010% (100 ppm). Typical drying conditions for crystallized granules are 2 hours at 90ºC or to a dew point of -40ºC, airflow rate of greater than 1.7 m³/kg per hour of resin throughput. Drying time must be increased to 3 hours or more for a 100 ppm residual moisture target. The resin should not be exposed to atmospheric conditions after drying. Keep the package sealed until ready to use and promptly reseal any unused material. Pellets that have been exposed to the atmosphere for extended time periods will require additional drying time. Amorphous regrind must be crystallized prior to drying, to assure efficient and effective drying.

# PROCESSING CONDITIONS (2)

| | |
|---|---|
| Melt Temperature | 200ºC |
| Feed Throat | 20ºC |
| Feed Temperature (crystalline pellets) | 165ºC |

| | |
|---|---|
| Feed Temperature (amorphous) | 150ºC |
| Compression Section | 195ºC |
| Metering Section | 210ºC |
| Nozzle | 210ºC |
| Mold | 25ºC |
| Screw Speed | 100-175 rpm |
| Back Pressure | 3 – 7 bars |
| Mold Shrinkage | 0.1 mm/mm. +/-0.01 |

(2) : These are starting points and may need to be optimized.

# Handling and storage

Futerro® PLA should be stored at ambient temperature and at atmospheric pressure in its original packaging bags The product should be stored in dry, well-ventilated areas, and it is recommended to avoid prolonged storage under extreme temperatures, direct sunlight or other sources of radiation.
It is advisable to convert the product within 12 months after delivery, provided appropriate storage conditions are used.
Please refer to the Safety Data Sheet for further information.

| | |
|---|---|
| CAS number | 9051-89-2 |

# Appendix A3 – Aspen Simulation Reports

## *Input Summary*

```
;
;Input Summary created by Aspen Plus Rel. 35.0 at 15:44:33 Thu Apr 6, 2017
;Directory S:\AspenTech\Aspen Plus V9.0\BSG Process V19 Compound_1  Filename
C:\Users\ageorg\AppData\Local\Temp\~apd349.txt
;


DYNAMICS
    DYNAMICS RESULTS=ON

IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm

DEF-STREAMS CONVEN ALL

SIM-OPTIONS MASS-BAL-CHE=YES

MODEL-OPTION

DATABANKS 'APV90 PURE35' / 'APV90 AQUEOUS' / 'APV90 SOLIDS' /  &
        'APV90 INORGANIC' / 'APEOSV90 AP-EOS' /  &
        'NISTV90 NIST-TRC' / 'APV90 ASPENPCD' / 'APV90 BIODIESEL' &
         / 'APV90 COMBUST' / 'APV90 ELECPURE' / 'APV90 EOS-LIT' &
         / 'APV90 ETHYLENE' / 'APV90 HYSYS' / 'APV90 INITIATO' &
         / 'APV90 NRTL-SAC' / 'APV90 PC-SAFT' / 'APV90 POLYMER' &
         / 'APV90 POLYPCSF' / 'APV90 PURE20' / 'APV90 PURE22' &
         / 'APV90 PURE24' / 'APV90 PURE25' / 'APV90 PURE26' /  &
        'APV90 PURE27' / 'APV90 PURE28' / 'APV90 PURE32' /  &
        'APV90 SEGMENT' / 'FACTV90 FACTPCD'

PROP-SOURCES 'APV90 PURE35' / 'APV90 AQUEOUS' / 'APV90 SOLIDS' &
         / 'APV90 INORGANIC' / 'APEOSV90 AP-EOS' /  &
        'NISTV90 NIST-TRC' / 'APV90 ASPENPCD' / 'APV90 BIODIESEL' &
         / 'APV90 COMBUST' / 'APV90 ELECPURE' / 'APV90 EOS-LIT' &
         / 'APV90 ETHYLENE' / 'APV90 HYSYS' / 'APV90 INITIATO' &
         / 'APV90 NRTL-SAC' / 'APV90 PC-SAFT' / 'APV90 POLYMER' &
         / 'APV90 POLYPCSF' / 'APV90 PURE20' / 'APV90 PURE22' &
         / 'APV90 PURE24' / 'APV90 PURE25' / 'APV90 PURE26' /  &
        'APV90 PURE27' / 'APV90 PURE28' / 'APV90 PURE32' /  &
        'APV90 SEGMENT' / 'FACTV90 FACTPCD'

COMPONENTS
    WATER H2O /
    GLUCOSE C6H12O6 /
    XYLOSE C5H10O5-D2 /
    AMMONIA NH4OH /
    OTHLIQUI D2O /
    H2SO4 H2SO4 /
    CAOH2 "CA(OH)2" /
    CASO4 CASO4 /
    OTHSOLID H2O2 /
    CELLULOS C6H12O6-N1 /
    "ENZ/XYL" C5H12O5 /
    NACIT NACL /
    LACTICAC C3H6O3-N1 /
    DIETHER C12H10O /
    N2 N2 /
    METHANOL CH4O /
    CH2CL2 CH2CL2 /
    ETHYL-01 C4H8O2-3 /
    PLA C12H26

SOLVE
    RUN-MODE MODE=SIM

FLOWSHEET
    BLOCK CAOH-NEU IN=XYSUGARS CAOH OUT=SUGARSX
    BLOCK AAS IN=NH3 4 OUT=AASPROD
    BLOCK FILTER IN=PROD-C OUT=XYSUGARS S5
    BLOCK SA-HYDRO IN=WETBSGH S11 OUT=PROD-H
    BLOCK WASH IN=BSG S2 OUT=WETBSGC
    BLOCK FUGEXYL IN=SUGARSX OUT=XYLSUGAR PREC-XYL
    BLOCK SACCH IN=NACIT ENZYMES SACHIN OUT=SUGARSP
    BLOCK FUGEPLA IN=SUGARSP OUT=PLASUGAR PREC-PLA
    BLOCK WASH2 IN=AASPROD AASWAT OUT=SACHIN
    BLOCK PLA-FERM IN=S21 OUT=1
    BLOCK LLE IN=S16 ETHIN2 OUT=S33 S31
    BLOCK XLAFERM IN=S23 OUT=3
    BLOCK EVAP IN=S20 OUT=STEAM4 5
    BLOCK COOL2 IN=S34 OUT=7
    BLOCK FILTER2 IN=7 OUT=8 9
    BLOCK WASH3 IN=9 OUT=11
    BLOCK CRYSTALL IN=11 OUT=LIQUOR XYLITOL
    BLOCK EVAP2 IN=S5 OUT=STEAM3 4
    BLOCK SPLIT IN=S36 OUT=PURGE RECYCLE
    BLOCK PSPLIT IN=S4 OUT=S9 S12
    BLOCK DRYPLA IN=S9 OUT=STEAM2 PLAREC
    BLOCK B1 IN=S26 OUT=WETBSGH
    BLOCK B2 IN=S1 PURE OUT=STOUT 2
    BLOCK B3 IN=STEAM2 STEAM1 OUT=S1
    BLOCK POLYHEAT IN=2 OUT=S3
    BLOCK PLAFLASH IN=S24 OUT=ETHPLA PLA
    BLOCK CHLMIX IN=PLA CH2CL2IN OUT=S7
    BLOCK POLYREAC IN=S3 PLAREC OUT=PLA1
    BLOCK B4 IN=MEOHIN S7 OUT=PLAOUT S8
    BLOCK ETHFLASH IN=S14 OUT=STEAM1 ETHOUT1
    BLOCK B11 IN=ETHPLA S12 OUT=S14 S13
    BLOCK WATPUR IN=STOUT OUT=WATER1 ETHOUT2
    BLOCK B5 IN=S6 S29 OUT=S10 S2
    BLOCK B6 IN=STEAM3 STEAM5 OUT=S6
    BLOCK B8 IN=S10 SA-IN OUT=S15 S11
    BLOCK B10 IN=WATER1 HOHIN S22 OUT=S19
    BLOCK B13 IN=S15 OUT=S22
    BLOCK B14 IN=ETHIN OUT=ETHIN2
    BLOCK B9 IN=1 OUT=S16 S17
    BLOCK CHROMA IN=S28 OUT=S18 S20
    BLOCK B15 IN=PLASUGAR OUT=S21
    BLOCK B16 IN=S25 OUT=S23
    BLOCK B17 IN=S13 OUT=S24
    BLOCK B12 IN=3 OUT=S27 S28
    BLOCK B18 IN=S8 OUT=X2 X1
    BLOCK B7 IN=ETHOUT1 ETHOUT2 OUT=ETHOUTFI
    BLOCK B19 IN=PLA1 STEAM4 OUT=S4 STEAM5
    BLOCK B20 IN=PROD-H WETBSGC OUT=PROD-C S26
    BLOCK B21 IN=S19 OUT=S29 S30
    BLOCK LLEREC IN=S31 OUT=WASTE S32
    BLOCK B25 IN=S32 S33 OUT=PURE
    BLOCK B22 IN=XYLSUGAR RECYCLE OUT=S25
    BLOCK B23 IN=5 8 OUT=S34 S36
```

```
PROPERTIES RK-ASPEN
    PROPERTIES IDEAL

STRUCTURES
    STRUCTURES CASO4 O1 S2 D / S2 O3 S / S2 O4 D / S2  &
        O5 S

PROP-DATA
    PROP-LIST ATOMNO / NOATOM
    PVAL CASO4 20 8 16 / 1. 4. 1.

PROP-DATA
    PROP-LIST ATOMNO / NOATOM
    PVAL PLA 6 1 8 / 3300. 4400. 2200.

ESTIMATE ALL

PROP-DATA AMMONIA
    IN-UNITS MET PRESSURE=MPa TEMPERATURE=C DELTA-T=C PDROP=bar  &
        INVERSE-PRES='1/bar' SHORT-LENGTH=mm
    PROP-LIST TCRKA / PC / TC
    PVAL AMMONIA 132.3 / 11.3 / 132.3

PROP-DATA AMMONIA
    IN-UNITS MET PRESSURE=bar TEMPERATURE=C DELTA-T=C PDROP=bar  &
        INVERSE-PRES='1/bar' SHORT-LENGTH=mm
    PROP-LIST PCRKA / OMGRKA / OMEGA
    PVAL AMMONIA 11.3 / 0.253 / 0.253

PROP-DATA CASO4
    IN-UNITS MET PRESSURE=bar TEMPERATURE=C DELTA-T=C  &
        MOLE-ENTHALP='kJ/mol' PDROP=bar INVERSE-PRES='1/bar'  &
        SHORT-LENGTH=mm
    PROP-LIST DHFORM / DHAQFM
    PVAL CASO4 -1432.7 / 17.8
    PVAL AMMONIA -366.719 / -4.019

PROP-DATA PCES-1
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROP-LIST VC / ZC / DHVLB / VB / RKTZRA / VLSTD
    PVAL AMMONIA 68.13756720 / .2284023160 / 25.69866910 /  &
        42.12300000 / .2676713990 / 42.12290000
    PROP-LIST VB / RKTZRA / VLSTD
    PVAL CASO4 405.4195630 / .2918596200 / 298.9063450
    PROP-LIST RKTZRA / VLSTD
    PVAL CAOH2 .2918596200 / 298.9063450
    PVAL LACTICAC .2089855090 / 68243.54800

PROP-DATA PLA
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' MOLE-VOLUME='ml/mol' HEAT=kJ  &
        INVERSE-PRES='1/bar' VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROP-LIST TB / TC / PC / VLSTD / TCRKA / PCRKA
    PVAL PLA 2000 / 3000 / 5 / 1 / 3000 / 5

PROP-DATA DHVLWT-1
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROP-LIST DHVLWT
    PVAL AMMONIA 29.32544000 -79.00000000 .1132839440  &
        .5389857650 -79.00000000
    PVAL LACTICAC 50.82247650 238.8450000 .3800000000 0.0  &
        238.8450000

PROP-DATA KLDIP-1
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROP-LIST KLDIP
    PVAL AMMONIA .1592361920 -5.5948563E-4 -3.7746675E-6  &
        4.96949013E-8 -2.954235E-10 -2.150000000 128.2455000

PROP-DATA MULAND-1
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROP-LIST MULAND
    PVAL AMMONIA 87.05270398 -3269.836150 -13.60519070  &
        -2.150000000 128.2455000
    PVAL CAOH2 80.86579468 -12127.32210 -10.25255770  &
        1126.850000 1706.850000
    PVAL CASO4 81.16998178 -12127.32210 -10.25255770  &
        1126.850000 1706.850000

PROP-DATA SIGDIP-1
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROP-LIST SIGDIP
    PVAL AMMONIA 167.5470060 1.222222220 1.7123181E-10  &
        -1.912316E-10 7.6645536E-11 -2.150000000 124.1910000
    PVAL LACTICAC 138.5197080 1.222222220 -5.192945E-10  &
        5.8323103E-10 -2.313469E-10 238.8450000 430.4900000

PROP-SET PS-1 TEMP KVL GAMMA KVL2 BETA MASSFRAC  &
        SUBSTREAM=MIXED COMPS=METHANOL CH2CL2 PHASE=V L1 L2

PROP-SET PS-2 TEMP KVL GAMMA KVL2 BETA MASSFRAC  &
        SUBSTREAM=MIXED COMPS=METHANOL CH2CL2 PHASE=V L1 L2

PROP-SET PS-3 TEMP KVL GAMMA KVL2 BETA MOLEFRAC  &
        SUBSTREAM=MIXED COMPS=PLA DIETHER PHASE=V L1 L2

PROP-SET PS-4 TEMP KVL GAMMA KVL2 BETA MOLEFRAC  &
        SUBSTREAM=MIXED COMPS=PLA DIETHER PHASE=V L1 L2

PROP-SET PS-5 TEMP KVL GAMMA KVL2 BETA MOLEFRAC  &
        SUBSTREAM=MIXED COMPS=WATER DIETHER PHASE=V L1 L2

STREAM AASWAT
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000
    MASS-FLOW WATER 50000.

STREAM BSG
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000
    MASS-FLOW WATER 98553.99997 / CELLULOS 61957.99999
```

```
STREAM CAOH
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000
    MASS-FLOW WATER 6375.899992 / CAOH2 1012.720000

STREAM CH2CL2IN
    SUBSTREAM MIXED TEMP=25. PRES=1.
    MASS-FLOW CH2CL2 80000.

STREAM ENZYMES
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000
    MASS-FLOW "ENZ/XYL" 15671.00000

STREAM ETHIN
    SUBSTREAM MIXED TEMP=141. PRES=1.
    MASS-FLOW DIETHER 40000.

STREAM HOHIN
    SUBSTREAM MIXED TEMP=25. PRES=1.
    MASS-FLOW WATER 100000.

STREAM MEOHIN
    SUBSTREAM MIXED TEMP=25. PRES=1.
    MASS-FLOW METHANOL 31638.

STREAM NACIT
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000
    MASS-FLOW NACIT 5201.000000

STREAM NH3
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000  &
        MASS-FLOW=29990.
    MASS-FRAC WATER 0.72 / AMMONIA 0.28

STREAM SA-IN
    SUBSTREAM MIXED TEMP=25.00000000 PRES=1.000000000
    MASS-FLOW WATER 1000. / H2SO4 1351.000000

BLOCK B3 MIXER
    PARAM

BLOCK B6 MIXER
    PARAM

BLOCK B7 MIXER
    PARAM

BLOCK B10 MIXER
    PARAM

BLOCK B14 MIXER
    PARAM

BLOCK B22 MIXER
    PARAM

BLOCK B25 MIXER
    PARAM

BLOCK CHLMIX MIXER
    PARAM PRES=1. NPHASE=1 PHASE=L T-EST=25.
    BLOCK-OPTION FREE-WATER=NO

BLOCK WASH MIXER
    PARAM

BLOCK WASH2 MIXER
    PARAM

BLOCK WASH3 MIXER
    PARAM

BLOCK PSPLIT FSPLIT
    FRAC S9 0.5

BLOCK SPLIT FSPLIT
    FRAC PURGE 0.5

BLOCK B4 SEP
    PARAM PRES=1. MAXIT=100 TOL=0.01
    FRAC STREAM=PLAOUT SUBSTREAM=MIXED COMPS=PLA FRACS=1.
    FLASH-SPECS PLAOUT KODE=NOFLASH
    PROPERTIES IDEAL FREE-WATER=IDEAL SOLU-WATER=3  &
        TRUE-COMPS=YES
    BLOCK-OPTION RESTART=YES ENERGY-BAL=YES FLASH-METHOD=GIBBS
    UTILITY UTILITY-ID=LPSTEAM

BLOCK B9 SEP
    PARAM
    FRAC STREAM=S16 SUBSTREAM=MIXED COMPS=WATER GLUCOSE  &
        XYLOSE OTHLIQUI LACTICAC DIETHER FRACS=1. 1. 1. 1.  &
        1. 1.
    UTILITY UTILITY-ID=LPSTEAM

BLOCK B12 SEP
    PARAM
    FRAC STREAM=S27 SUBSTREAM=MIXED COMPS=OTHSOLID CELLULOS  &
        FRACS=1. 1.

BLOCK B21 SEP
    PARAM
    FRAC STREAM=S30 SUBSTREAM=MIXED COMPS=WATER GLUCOSE  &
        XYLOSE AMMONIA OTHLIQUI H2SO4 CAOH2 CASO4 OTHSOLID  &
        CELLULOS "ENZ/XYL" NACIT LACTICAC DIETHER N2 METHANOL  &
        CH2CL2 ETHYL-01 PLA FRACS=0. 0. 0. 0. 1. 0. 0. 0.  &
        1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

BLOCK CHROMA SEP
    PARAM
    FRAC STREAM=S18 SUBSTREAM=MIXED COMPS=OTHLIQUI CASO4  &
        OTHSOLID CELLULOS FRACS=1. 1. 1. 1.

BLOCK CRYSTALL SEP
    PARAM
    FRAC STREAM=XYLITOL SUBSTREAM=MIXED COMPS=WATER GLUCOSE  &
        XYLOSE AMMONIA OTHLIQUI H2SO4 CAOH2 CASO4 OTHSOLID  &
        CELLULOS "ENZ/XYL" NACIT LACTICAC DIETHER N2 METHANOL  &
        CH2CL2 ETHYL-01 FRACS=0. 0. 0. 0. 0. 0. 0. 0. 0.  &
        0. 1. 0. 0. 0. 0. 0. 0. 0.

BLOCK FILTER SEP
    PARAM
    FRAC STREAM=XYSUGARS SUBSTREAM=MIXED COMPS=WATER GLUCOSE  &
        XYLOSE AMMONIA OTHLIQUI H2SO4 CAOH2 CASO4 OTHSOLID  &
        CELLULOS "ENZ/XYL" NACIT FRACS=0.1129 1. 1. 0. 1. 1.  &
        0. 0. 0. 0. 0. 0.

BLOCK FILTER2 SEP
    PARAM
    FRAC STREAM=9 SUBSTREAM=MIXED COMPS=WATER GLUCOSE XYLOSE  &
        AMMONIA OTHLIQUI H2SO4 CAOH2 CASO4 OTHSOLID CELLULOS  &
        "ENZ/XYL" NACIT LACTICAC DIETHER N2 METHANOL CH2CL2  &
```

```
        ETHYL-01 FRACS=0.2 0. 0. 0. 0. 0. 0. 0. 0. 0.  &
        0.85 0. 0. 0. 0. 0. 0. 0.

BLOCK FUGEPLA SEP
    PARAM
    FRAC STREAM=PLASUGAR SUBSTREAM=MIXED COMPS=WATER GLUCOSE  &
        XYLOSE AMMONIA OTHLIQUI H2SO4 CAOH2 CASO4 OTHSOLID  &
        CELLULOS "ENZ/XYL" NACIT FRACS=0.95 1. 1. 0. 1. 0.  &
        0. 0. 0. 0. 0. 0.

BLOCK FUGEXYL SEP
    PARAM
    FRAC STREAM=XYLSUGAR SUBSTREAM=MIXED COMPS=WATER GLUCOSE  &
        XYLOSE AMMONIA OTHLIQUI H2SO4 CAOH2 CASO4 OTHSOLID  &
        CELLULOS "ENZ/XYL" NACIT FRACS=0.98 1. 1. 0. 1. 0.  &
        0. 0. 0. 0. 0. 0.

BLOCK LLEREC SEP
    PARAM
    FRAC STREAM=S32 SUBSTREAM=MIXED COMPS=WATER LACTICAC  &
        FRACS=0. 0.95

BLOCK B1 HEATER
    PARAM TEMP=150. PRES=1. DPPARMOPT=NO
    UTILITY UTILITY-ID=MPSTEAM

BLOCK B13 HEATER
    PARAM PRES=1. VFRAC=0. DPPARMOPT=NO
    UTILITY UTILITY-ID=COOLINGW

BLOCK B15 HEATER
    PARAM TEMP=37. PRES=1. DPPARMOPT=NO
    UTILITY UTILITY-ID=LPSTEAM

BLOCK B16 HEATER
    PARAM TEMP=32. PRES=1. DPPARMOPT=NO
    UTILITY UTILITY-ID=LPSTEAM

BLOCK B17 HEATER
    PARAM TEMP=288. PRES=1. MAXIT=100 TOL=0.001 DPPARMOPT=NO
    UTILITY UTILITY-ID=FURNACE

BLOCK COOL2 HEATER
    PARAM TEMP=5. PRES=1.000000000 DPPARMOPT=NO
    UTILITY UTILITY-ID=REFRIDGE

BLOCK POLYHEAT HEATER
    PARAM TEMP=170. PRES=1. DPPARMOPT=NO
    UTILITY UTILITY-ID=NONCONDS

BLOCK DRYPLA FLASH2
    PARAM TEMP=110. PRES=1.
    UTILITY UTILITY-ID=COOLINGW

BLOCK ETHFLASH FLASH2
    PARAM TEMP=170. PRES=1.
    UTILITY UTILITY-ID=AIR

BLOCK EVAP FLASH2
    PARAM PRES=1.000000000 VFRAC=0.9 NPHASE=2
    BLOCK-OPTION FREE-WATER=NO
    UTILITY UTILITY-ID=LPSTEAM

BLOCK EVAP2 FLASH2
    PARAM TEMP=110.0000000 VFRAC=0.1
    UTILITY UTILITY-ID=ELEC

BLOCK PLAFLASH FLASH2
    PARAM TEMP=288. PRES=1. MAXIT=40 TOL=0.005

BLOCK WATPUR DECANTER
    PARAM TEMP=90. PRES=1. L2-COMPS=DIETHER MAXIT=50 TOL=0.1

BLOCK B2 HEATX
    PARAM T-HOT=90. CALC-TYPE=DESIGN MIN-TAPP=1. U-OPTION=PHASE  &
        F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=S1 COLD=PURE
    OUTLETS-HOT STOUT
    OUTLETS-COLD 2
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK B5 HEATX
    PARAM T-COLD=95. CALC-TYPE=DESIGN MIN-TAPP=10.  &
        U-OPTION=PHASE F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=S6 COLD=S29
    OUTLETS-HOT S10
    OUTLETS-COLD S2
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK B8 HEATX
    PARAM T-COLD=92. CALC-TYPE=DESIGN MIN-TAPP=10.  &
        U-OPTION=PHASE F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=S10 COLD=SA-IN
    OUTLETS-HOT S15
    OUTLETS-COLD S11
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK B11 HEATX
    PARAM T-HOT=180. CALC-TYPE=DESIGN U-OPTION=PHASE  &
        F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=ETHPLA COLD=S12
    OUTLETS-HOT S14
    OUTLETS-COLD S13
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK B19 HEATX
    PARAM T-HOT=110. CALC-TYPE=DESIGN U-OPTION=PHASE  &
        F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=PLA1 COLD=STEAM4
    OUTLETS-HOT S4
    OUTLETS-COLD STEAM5
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK B20 HEATX
    PARAM DELT-COLD=10. CALC-TYPE=DESIGN U-OPTION=PHASE  &
        F-OPTION=CONSTANT CALC-METHOD=SHORTCUT
    FEEDS HOT=PROD-H COLD=WETBSGC
    OUTLETS-HOT PROD-C
    OUTLETS-COLD S26
    HOT-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    COLD-SIDE DP-OPTION=CONSTANT DPPARMOPT=NO
    TQ-PARAM CURVE=YES
```

```
BLOCK B23 HEATX
    PARAM T-COLD=95.
    FEEDS HOT=5 COLD=8
    OUTLETS-HOT S34
    OUTLETS-COLD S36
    HOT-SIDE DPPARMOPT=NO
    COLD-SIDE DPPARMOPT=NO
    TQ-PARAM CURVE=YES

BLOCK B18 DSTWU
    PARAM LIGHTKEY=CH2CL2 RECOVL=0.5858 HEAVYKEY=METHANOL  &
        RECOVH=0.001 PTOP=1. PBOT=1. NSTAGE=10 MAXIT=100  &
        FLASH-MAXIT=100

BLOCK LLE EXTRACT
    PARAM NSTAGE=5
    FEEDS ETHIN2 5 / S16 1
    PRODUCTS S31 5 L1 / S33 1 L2
    P-SPEC 1 1.000000000 / 2 1.000000000 / 3 1.000000000 /  &
        4 1.000000000 / 5 1.000000000
    T-SPEC 1 34.50000000 / 2 31.80000000 / 3 29.00000000 /  &
        4 26.00000000 / 5 22.70000000
    L1-COMPS WATER
    L2-COMPS LACTICAC DIETHER

BLOCK CAOH-NEU RSTOIC
    PARAM TEMP=25.00000000 PRES=1.000000000 NPHASE=2
    STOIC 1 MIXED H2SO4 -1. / CAOH2 -1. / CASO4 1. /  &
        WATER 2.
    CONV 1 MIXED CAOH2 0.95
    BLOCK-OPTION FREE-WATER=NO
    UTILITY UTILITY-ID=COOLINGW

BLOCK POLYREAC RSTOIC
    PARAM TEMP=170. PRES=1. NPHASE=2
    STOIC 1 MIXED LACTICAC -1100. / WATER 1100. / PLA 1.
    CONV 1 MIXED LACTICAC 1.
    BLOCK-OPTION FREE-WATER=NO
    UTILITY UTILITY-ID=HPSTEAM

BLOCK AAS RYIELD
    PARAM TEMP=70.00000000 PRES=1.000000000
    MASS-YIELD MIXED OTHLIQUI 1.
    UTILITY UTILITY-ID=COOLINGW
    INERTS WATER / AMMONIA / OTHSOLID

BLOCK PLA-FERM RYIELD
    PARAM TEMP=37.00000000 PRES=1.000000000
    MASS-YIELD MIXED LACTICAC 0.99 / GLUCOSE 0.01 / OTHSOLID  &
        0.1
    INERTS WATER / OTHLIQUI / "ENZ/XYL" / NACIT

BLOCK SA-HYDRO RYIELD
    PARAM TEMP=150.0000000 PRES=1.000000000
    MASS-YIELD MIXED CELLULOS 0.247 / XYLOSE 0.209 / OTHSOLID  &
        0.063 / OTHLIQUI 0.481
    INERTS WATER / H2SO4 / "ENZ/XYL" / DIETHER / GLUCOSE

BLOCK SACCH RYIELD
    PARAM TEMP=25.00000000 PRES=1.000000000
    MASS-YIELD MIXED GLUCOSE 1.
    INERTS WATER / AMMONIA / OTHSOLID / "ENZ/XYL" / NACIT

BLOCK XLAFERM RYIELD
    PARAM TEMP=32.00000000 PRES=1.000000000
    MASS-YIELD MIXED "ENZ/XYL" 0.8684 / XYLOSE 0.1316 /  &
        OTHSOLID 0.1
    INERTS WATER / OTHLIQUI

STREAM-PRICE
    STREAM-PRICE STREAM=AASWAT VOL-PRICE=7.26473142E-4 /  &
        STREAM=BSG MASS-PRICE=0.0 / STREAM=CAOH  &
        MASS-PRICE=.1760000000 / STREAM=ENZYMES  &
        MASS-PRICE=.5070000000 / STREAM=LIQUOR MASS-PRICE=0.0 /  &
        STREAM=NACIT MASS-PRICE=1.918021681 / STREAM=NH3  &
        MASS-PRICE=.3000000000 / STREAM=PREC-PLA MASS-PRICE=0.0 /  &
        STREAM=PREC-XYL MASS-PRICE=0.0 / STREAM=PURE  &
        MASS-PRICE=0.0 / STREAM=SA-IN MASS-PRICE=.2755778277 /  &
        STREAM=STEAM3 MASS-PRICE=0.0 / STREAM=STEAM4  &
        MASS-PRICE=0.0 / STREAM=XYLITOL MASS-PRICE=1.433000000

UTILITY AIR GENERAL
    DESCRIPTION "Air, Inlet Temp=30 C, Outlet Temp=35 C"
    COST ENERGY-PRICE=0. <$/kJ>
    PARAM UTILITY-TYPE=GENERAL COOLING-VALU=-5. <kJ/kg> TIN=30.  &
        TOUT=35. MIN-TAPP=10. HTC=0.0003996 <GJ/hr-sqm-C>

UTILITY COOLINGW GENERAL
    DESCRIPTION "Cooling Water, Inlet Temp=20 C, Outlet Temp=25 C"
    COST ENERGY-PRICE=2.12E-007 <$/kJ>
    PARAM UTILITY-TYPE=WATER PRES=1. PRES-OUT=1. TIN=20.  &
        TOUT=25. CALOPT=FLASH MIN-TAPP=5. HTC=0.0135 <GJ/hr-sqm-C>

UTILITY ELEC GENERAL
    DESCRIPTION "Electrical Utility"
    COST ELEC-PRICE=0.0775 <$/kWhr>
    PARAM UTILITY-TYPE=ELECTRICITY CALCCO2=YES FACTORSOURCE= &
        "US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=0.58

UTILITY FURNACE GENERAL
    DESCRIPTION  &
        "Fired Heater, Inlet Temp=1000 C, Outlet Temp=400 C"
    COST ENERGY-PRICE=4.25E-006 <$/kJ>
    PARAM UTILITY-TYPE=GENERAL COOLING-VALU=600. <kJ/kg>  &
        TIN=1000. TOUT=400. MIN-TAPP=25. CALCCO2=YES  &
        FACTORSOURCE="US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=0.85  &
        HTC=0.0003996 <GJ/hr-sqm-C>

UTILITY HPSTEAM GENERAL
    DESCRIPTION  &
        "High Pressure Steam, Inlet Temp=250 C, Outlet Temp=249 C, Pres=572 psia"
    COST ENERGY-PRICE=2.5E-006 <$/kJ>
    PARAM UTILITY-TYPE=STEAM TIN=250. TOUT=249. VFRAC=1.  &
        VFR-OUT=0. CALOPT=FLASH MIN-TAPP=10. CALCCO2=YES  &
        FACTORSOURCE="US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=0.85  &
        HTC=0.0216 <GJ/hr-sqm-C>

UTILITY LPSTEAM GENERAL
    DESCRIPTION  &
        "Low Pressure Steam, Inlet Temp=125 C, Outlet Temp=124 C"
    COST ENERGY-PRICE=1.9E-006 <$/kJ>
    PARAM UTILITY-TYPE=STEAM TIN=125. TOUT=124. VFRAC=1.  &
        VFR-OUT=0. CALOPT=FLASH MIN-TAPP=10. CALCCO2=YES  &
        FACTORSOURCE="US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=0.85  &
        HTC=0.0216 <GJ/hr-sqm-C>

UTILITY MPSTEAM GENERAL
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    DESCRIPTION  &
        "Medium Pressure Steam, Inlet Temp=175 C, Outlet Temp=174 C, Pres=127 psia"
    COST ENERGY-PRICE=2.2E-006 <$/kJ>
    PARAM UTILITY-TYPE=STEAM TIN=175. TOUT=174. VFRAC=1.  &
        VFR-OUT=0. CALOPT=FLASH MIN-TAPP=10. CALCCO2=YES  &
        FACTORSOURCE="US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=0.85  &
        HTC=0.0216 <GJ/hr-sqm-C>

UTILITY NONCONDS GENERAL
    DESCRIPTION  &
        "Medium Pressure Steam, Inlet Temp=175 C, Outlet Temp=174 C, Pres=127 psia"
    COST ENERGY-PRICE=2.2E-006 <$/kJ>
    PARAM UTILITY-TYPE=STEAM TIN=175. TOUT=150. VFRAC=1.  &
        VFR-OUT=0.5 CALOPT=FLASH MIN-TAPP=10. CALCCO2=YES  &
        FACTORSOURCE="US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=0.85  &
        HTC=0.0216 <GJ/hr-sqm-C>

UTILITY REFRIDGE GENERAL
    DESCRIPTION  &
        "Refrigerant 1, Inlet Temp=-25 C, Outlet Temp=-24 C"
    COST ENERGY-PRICE=2.74E-006 <$/kJ>
    PARAM UTILITY-TYPE=REFRIGERATIO COOLING-VALU=-4. <kJ/kg>  &
        TIN=-25. TOUT=-24. MIN-TAPP=3. CALCCO2=YES FACTORSOURCE= &
        "US-EPA-Rule-E9-5711" FUELSOURCE="Natural_gas"  &
        CO2FACTOR=2.34000000E-7 EFFICIENCY=1.  &
        HTC=0.00468 <GJ/hr-sqm-C>

DESIGN-SPEC CH2CL2
    DEFINE CH2CL3VO STDVOL-FLOW STREAM=S7 SUBSTREAM=MIXED  &
        COMPONENT=CH2CL2 UOM="l/day"
    DEFINE SOLMASS MASS-FLOW STREAM=S7 SUBSTREAM=MIXED  &
        COMPONENT=PLA UOM="kg/day"
    SPEC "CH2CL3VO/SOLMASS" TO "7.46"
    TOL-SPEC "0.1"
    VARY MASS-FLOW STREAM=CH2CL2IN SUBSTREAM=MIXED  &
        COMPONENT=CH2CL2 UOM="kg/day"
    LIMITS "10" "100000" STEP-SIZE=1.

DESIGN-SPEC DICHLIN
    DEFINE DICHL MASS-FLOW STREAM=S8 SUBSTREAM=MIXED  &
        COMPONENT=CH2CL2 UOM="kg/day"
    SPEC "DICHL" TO "70000"
    TOL-SPEC "0.001"
    VARY MASS-FLOW STREAM=CH2CL2IN SUBSTREAM=MIXED  &
        COMPONENT=CH2CL2 UOM="kg/day"
    LIMITS "-300" "300" STEP-SIZE=1.

DESIGN-SPEC ETHERIN
    DEFINE ETHERIN MASS-FLOW STREAM=ETHIN2 SUBSTREAM=MIXED  &
        COMPONENT=DIETHER UOM="kg/day"
    SPEC "ETHERIN" TO "40000"
    TOL-SPEC "1"
    VARY MASS-FLOW STREAM=ETHIN SUBSTREAM=MIXED  &
        COMPONENT=DIETHER UOM="kg/day"
    LIMITS "0" "40000" STEP-SIZE=0.0001

DESIGN-SPEC ETHERSPL
    DEFINE ETHER MASS-FRAC STREAM=ETHOUT1 SUBSTREAM=MIXED  &
        COMPONENT=DIETHER
    SPEC "ETHER" TO "0.99"
    TOL-SPEC "0.001"
    VARY BLOCK-VAR BLOCK=ETHFLASH VARIABLE=TEMP SENTENCE=PARAM  &
        UOM="C"
    LIMITS "10" "300" STEP-SIZE=0.01
```

```
DESIGN-SPEC METHANOL
    DEFINE METHANOL STDVOL-FLOW STREAM=S8 SUBSTREAM=MIXED  &
        COMPONENT=METHANOL UOM="l/day"
    DEFINE CH2CL2 STDVOL-FLOW STREAM=S8 SUBSTREAM=MIXED  &
        COMPONENT=CH2CL2 UOM="l/day"
    SPEC "METHANOL/CH2CL2" TO "0.75"
    TOL-SPEC "0.01"
    VARY MASS-FLOW STREAM=MEOHIN SUBSTREAM=MIXED  &
        COMPONENT=METHANOL UOM="kg/day"
    LIMITS "10" "100000" STEP-SIZE=0.5

DESIGN-SPEC METHIN
    DEFINE METHIN MASS-FLOW STREAM=S8 SUBSTREAM=MIXED  &
        COMPONENT=METHANOL UOM="kg/day"
    SPEC "METHIN" TO "31638"
    TOL-SPEC "0.001"
    VARY MASS-FLOW STREAM=MEOHIN SUBSTREAM=MIXED  &
        COMPONENT=METHANOL UOM="kg/day"
    LIMITS "-100" "100" STEP-SIZE=0.0001

DESIGN-SPEC PLAFERWA
    DEFINE PLAWATER MASS-FLOW STREAM=PLASUGAR SUBSTREAM=MIXED  &
        COMPONENT=GLUCOSE UOM="kg/day"
    DEFINE VOL STREAM-VAR STREAM=PLASUGAR SUBSTREAM=MIXED  &
        VARIABLE=STDVOL-FLOW UOM="l/day"
    SPEC "PLAWATER/VOL" TO "0.05"
    TOL-SPEC "0.001"
    VARY BLOCK-VAR BLOCK=EVAP2 VARIABLE=TEMP SENTENCE=PARAM UOM= &
        "C"
    LIMITS "50" "200" STEP-SIZE=1.

DESIGN-SPEC PLARE
    DEFINE WATCONC MASS-FRAC STREAM=PLAREC SUBSTREAM=MIXED  &
        COMPONENT=WATER
    SPEC "WATCONC" TO "0.02"
    TOL-SPEC "0.001"
    VARY BLOCK-VAR BLOCK=DRYPLA VARIABLE=TEMP SENTENCE=PARAM  &
        UOM="C"
    LIMITS "70" "200" STEP-SIZE=1.

DESIGN-SPEC WATERIN
    DEFINE WATERFLO MASS-FLOW STREAM=S19 SUBSTREAM=MIXED  &
        COMPONENT=WATER UOM="kg/day"
    SPEC "WATERFLO" TO "355801"
    TOL-SPEC "1"
    VARY MASS-FLOW STREAM=HOHIN SUBSTREAM=MIXED COMPONENT=WATER  &
        UOM="kg/day"
    LIMITS "20000" "400000" STEP-SIZE=0.5

DESIGN-SPEC XYFERMWA
    DEFINE XYLOSE MASS-FLOW STREAM=S23 SUBSTREAM=MIXED  &
        COMPONENT=XYLOSE UOM="kg/day"
    DEFINE VOL STREAM-VAR STREAM=S23 SUBSTREAM=MIXED  &
        VARIABLE=STDVOL-FLOW UOM="l/day"
    SPEC "XYLOSE/VOL" TO "0.08"
    TOL-SPEC "0.001"
    VARY BLOCK-VAR BLOCK=FILTER SENTENCE=FRAC VARIABLE=FRACS  &
        ID1=MIXED ID2=XYSUGARS ELEMENT=1
    LIMITS "0.05" "0.9" STEP-SIZE=1.

EO-CONV-OPTI

SENSITIVITY DISTIL
    DEFINE METH MASS-FRAC STREAM=X2 SUBSTREAM=MIXED  &
        COMPONENT=METHANOL
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    TABULATE 1 "METH"
    VARY BLOCK-VAR BLOCK=B18 VARIABLE=RECOVL SENTENCE=PARAM
    RANGE OPT-LIST=RANGE LOWER="0" UPPER="1" NPOINT="100"

SENSITIVITY LLESENS
    DEFINE PURELAC MASS-FLOW STREAM=PURE SUBSTREAM=MIXED  &
        COMPONENT=LACTICAC UOM="kg/day"
    DEFINE PUREWAT MASS-FLOW STREAM=PURE SUBSTREAM=MIXED  &
        COMPONENT=WATER UOM="kg/day"
    DEFINE PURELACF MASS-FRAC STREAM=PURE SUBSTREAM=MIXED  &
        COMPONENT=LACTICAC
    DEFINE WASTELAC MASS-FLOW STREAM=WASTE SUBSTREAM=MIXED  &
        COMPONENT=LACTICAC UOM="kg/day"
    DEFINE WASTEWAT MASS-FLOW STREAM=WASTE SUBSTREAM=MIXED  &
        COMPONENT=WATER UOM="kg/day"
    TABULATE 1 "PURELAC"
    TABULATE 2 "PUREWAT"
    TABULATE 3 "PURELACF"
    TABULATE 4 "WASTELAC"
    TABULATE 5 "WASTEWAT"
    VARY MASS-FLOW STREAM=ETHIN2 SUBSTREAM=MIXED  &
        COMPONENT=DIETHER UOM="kg/day"
    RANGE OPT-LIST=RANGE LOWER="1000" UPPER="100000"  &
        NPOINT="500"

SENSITIVITY LLEWATER
    DEFINE LACWAT MASS-FLOW STREAM=WASTE SUBSTREAM=MIXED  &
        COMPONENT=LACTICAC UOM="kg/day"
    DEFINE LACETHER MASS-FLOW STREAM=PURE SUBSTREAM=MIXED  &
        COMPONENT=LACTICAC UOM="kg/day"
    DEFINE LACFEED MASS-FLOW STREAM=S16 SUBSTREAM=MIXED  &
        COMPONENT=LACTICAC UOM="kg/day"
    TABULATE 1 "LACWAT"
    TABULATE 2 "LACETHER"
    TABULATE 3 "LACFEED"
    VARY MASS-FLOW STREAM=S16 SUBSTREAM=MIXED COMPONENT=WATER  &
        UOM="kg/day"
    RANGE OPT-LIST=RANGE LOWER="100000" UPPER="400000"  &
        NPOINT="100"

CONV-OPTIONS
    PARAM TEAR-METHOD=BROYDEN TOL=0.001
    WEGSTEIN MAXIT=100
    BROYDEN MAXIT=100

STREAM-REPOR MOLEFLOW

PROPERTY-REP PCES

PROP-TABLE BINRY-1 FLASHCURVE
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    MASS-FLOW METHANOL 1 /  CH2CL2  1
    STATE VFRAC=0.0
    VARY PRES
    RANGE LIST=1.000000000
    VARY MASSFRAC COMP=METHANOL
    RANGE VARVALUE=RANGE LOWER=0.0 UPPER=1.0 NPOINT=50
    PARAM NPHASE=3
    TABULATE PROPERTIES=PS-1

PROP-TABLE BINRY-2 FLASHCURVE
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    MASS-FLOW METHANOL 1 /  CH2CL2  1
    STATE VFRAC=0.0
    VARY PRES
    RANGE LIST=1.000000000
    VARY MASSFRAC COMP=CH2CL2
    RANGE VARVALUE=RANGE LOWER=0.0 UPPER=1.0 NPOINT=50
    PARAM NPHASE=3
    TABULATE PROPERTIES=PS-2

PROP-TABLE BINRY-3 FLASHCURVE
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    MOLE-FLOW PLA 1 /  DIETHER  1
    STATE VFRAC=0.0
    VARY PRES
    RANGE LIST=1.000000000
    VARY MOLEFRAC COMP=PLA
    RANGE VARVALUE=RANGE LOWER=0.0 UPPER=1.0 NPOINT=50
    PARAM NPHASE=3
    TABULATE PROPERTIES=PS-3

PROP-TABLE BINRY-4 FLASHCURVE
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROPERTIES RK-ASPEN FREE-WATER=STEAM-TA SOLU-WATER=3  &
        TRUE-COMPS=YES
    MOLE-FLOW PLA 1 /  DIETHER  1
    STATE VFRAC=0.0
    VARY PRES
    RANGE LIST=1.000000000
    VARY MOLEFRAC COMP=DIETHER
    RANGE VARVALUE=RANGE LOWER=0.0 UPPER=1.0 NPOINT=50
    PARAM NPHASE=3
    TABULATE PROPERTIES=PS-4

PROP-TABLE BINRY-5 FLASHCURVE
    IN-UNITS MET ENTHALPY='J/kg' FLOW='kg/day' MASS-FLOW='kg/day'  &
        MOLE-FLOW='mol/hr' VOLUME-FLOW='l/day' ENTHALPY-FLO=kW  &
        TEMPERATURE=C DELTA-T=C MOLE-ENTHALP='kJ/mol'  &
        MASS-ENTHALP='J/kg' HEAT=kJ INVERSE-PRES='1/bar'  &
        VOL-ENTHALPY='kJ/cum' SHORT-LENGTH=mm
    PROPERTIES RK-ASPEN FREE-WATER=STEAM-TA SOLU-WATER=3  &
        TRUE-COMPS=YES
    MOLE-FLOW WATER 1 /  DIETHER  1
    STATE VFRAC=0.0
    VARY PRES
    RANGE LIST=1.000000000
    VARY MOLEFRAC COMP=DIETHER
    RANGE VARVALUE=RANGE LOWER=0.0 UPPER=1.0 NPOINT=50
    PARAM NPHASE=3
    TABULATE PROPERTIES=PS-5

DISABLE
    SENSITIVITY DISTIL LLESENS LLEWATER
    DESIGN-SPEC CH2CL2 DICHLIN ETHERIN METHIN PLAFERWA
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# Stream Report

STREAM COSTS

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

1 11 2 3 4

| STREAM ID | 1 | 11 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| FROM : | PLA-FERM | WASH3 | B2 | XLAFERM | EVAP2 |
| TO : | B9 | CRYSTALL | POLYHEAT | B12 | AAS |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 8.1648+05 | 5379.6749 | 887.7925 | 3.0202+05 | 6.9387+05 |
| GLUCOSE | 32.1773 | 0.0 | 32.1773 | 0.0 | 0.0 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 488.7400 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 6.2002+04 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 1704.2599 | 0.0 | 0.0 | 1639.1820 | 4695.8931 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 3539.4099 |
| ENZ/XYL | 0.0 | 2704.7653 | 0.0 | 3182.3591 | 0.1088 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 6371.1031 | 0.0 | 6163.4740 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 9791.7798 | 0.0 | 2.7190-09 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 8.2459+05 | 8084.4402 | 1.6875+04 | 3.6933+05 | 7.0210+05 |
| KG/DAY | 3.6832+05 | 1.2203+04 | 5.3848+04 | 1.7510+05 | 3.1914+05 |
| L/DAY | 4.8787+05 | 1.1175+04 | 6.3084+04 | 2.2213+05 | 4.4233+05 |
| STATE VARIABLES: | | | | | |
| TEMP C | 37.0000 | 5.0000 | 93.1981 | 32.0000 | 110.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.2993 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -290.6723 | -547.5449 | -261.9231 | -296.4972 | -285.4353 |
| J/KG | -1.5618+07 | -8.7062+06 | -1.9700+06 | -1.5009+07 | -1.5071+07 |
| KW | -6.6579+04 | -1229.6094 | -1227.7808 | -3.0418+04 | -5.5668+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -43.6936 | -102.8881 | -259.2704 | -41.2931 | -36.6408 |
| CAL/GM-K | -2.3477 | -1.6360 | -1.9501 | -2.0903 | -1.9346 |
| DENSITY: | | | | | |
| MOL/CC | 4.0564-02 | 1.7362-02 | 6.4201-03 | 3.9903-02 | 3.8095-02 |
| GM/CC | 0.7550 | 1.0919 | 0.8536 | 0.7883 | 0.7215 |
| AVG MW | 18.6115 | 62.8911 | 132.9556 | 19.7547 | 18.9397 |

5 7 8 9 AASPROD

| STREAM ID | 5 | 7 | 8 | 9 | AASPROD |
|---|---|---|---|---|---|
| FROM : | EVAP | COOL2 | FILTER2 | FILTER2 | AAS |
| TO : | B23 | FILTER2 | B23 | WASH3 | WASH2 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 2.6898+04 | 2.6898+04 | 2.1519+04 | 5379.6749 | 7.4381+05 |
| GLUCOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| XYLOSE | 488.6902 | 488.6902 | 488.7000 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 9983.5910 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 3.1840+04 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 4695.8931 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 3182.0769 | 3182.0769 | 477.3211 | 2704.7653 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 3.0569+04 | 3.0569+04 | 2.2485+04 | 8084.4402 | 7.9033+05 |
| KG/DAY | 2.5010+04 | 2.5010+04 | 1.2808+04 | 1.2203+04 | 3.4913+05 |
| L/DAY | 2.8025+04 | 2.6229+04 | 1.4946+04 | 1.1175+04 | 9.2381+06 |
| STATE VARIABLES: | | | | | |
| TEMP C | 103.3036 | 5.0000 | 5.0000 | 5.0000 | 70.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 1.7092-02 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9829 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|---|---|---|---|---|---|
| ENTHALPY: | | | | | |
| KJ/MOL | -370.3653 | -380.9917 | -322.1541 | -547.5449 | -285.5104 |
| J/KG | -1.0864+07 | -1.1176+07 | -1.3573+07 | -8.7062+06 | -1.5511+07 |
| KW | -3144.9305 | -3235.1634 | -2012.1472 | -1229.6094 | -6.2680+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -55.2974 | -63.1045 | -49.5701 | -102.8881 | -40.7199 |
| CAL/GM-K | -1.6221 | -1.8511 | -2.0886 | -1.6360 | -2.2123 |
| DENSITY: | | | | | |
| MOL/CC | 2.6179-02 | 2.7971-02 | 3.6106-02 | 1.7362-02 | 2.0532-03 |
| GM/CC | 0.8924 | 0.9535 | 0.8570 | 1.0919 | 3.7793-02 |
| AVG MW | 34.0897 | 34.0897 | 23.7341 | 62.8911 | 18.4065 |

AASWAT BSG CAOH CH2CL2IN ENZYMES
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| STREAM ID | AASWAT | BSG | CAOH | CH2CL2IN | ENZYMES |
|---|---|---|---|---|---|
| FROM : | ---- | ---- | ---- | ---- | ---- |
| TO : | WASH2 | WASH | CAOH-NEU | CHLMIX | SACCH |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 1.1564+05 | 2.2794+05 | 1.4747+04 | 0.0 | 0.0 |
| GLUCOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 569.5119 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 1.4330+04 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 4291.6202 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 3.9247+04 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COST: | | | | | |
| $/HR | 2.0027 | 0.0 | 54.1832 | MISSING | 331.0499 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 1.1564+05 | 2.4227+05 | 1.5316+04 | 3.9247+04 | 4291.6202 |
| KG/DAY | 5.0000+04 | 1.6051+05 | 7388.6200 | 8.0000+04 | 1.5671+04 |
| L/DAY | 6.6162+04 | 1.7829+05 | 1.2918+04 | 7.0102+04 | 1.2718+04 |
| STATE VARIABLES: | | | | | |
| TEMP C | 25.0000 | 25.0000 | 25.0000 | 25.0000 | 25.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -288.8616 | -345.0984 | -299.4644 | -124.3324 | -1062.5192 |
| J/KG | -1.6034+07 | -1.2501+07 | -1.4898+07 | -1.4639+06 | -6.9835+06 |
| KW | -9279.0822 | -2.3224+04 | -1274.0564 | -1355.4630 | -1266.6469 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -40.8242 | -54.2020 | -38.1571 | -43.2094 | -227.4091 |
| CAL/GM-K | -2.2661 | -1.9634 | -1.8983 | -0.5088 | -1.4947 |
| DENSITY: | | | | | |
| MOL/CC | 4.1949-02 | 3.2612-02 | 2.8455-02 | 1.3436-02 | 8.0988-03 |
| GM/CC | 0.7557 | 0.9003 | 0.5720 | 1.1412 | 1.2322 |
| AVG MW | 18.0153 | 27.6055 | 20.1005 | 84.9323 | 152.1473 |

ETHIN ETHIN2 ETHOUT1 ETHOUT2 ETHOUTFI
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| STREAM ID | ETHIN | ETHIN2 | ETHOUT1 | ETHOUT2 | ETHOUTFI |
|---|---|---|---|---|---|
| FROM : | ---- | B14 | ETHFLASH | WATPUR | B7 |
| TO : | B14 | LLE | B7 | B7 | ---- |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 0.0 | 0.0 | 610.0397 | 45.0061 | 655.0458 |
| GLUCOSE | 0.0 | 0.0 | 32.1530 | 2.9138-06 | 32.1530 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 9791.7798 | 9791.7798 | 9544.6563 | 242.5761 | 9787.2324 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 9791.7798 | 9791.7798 | 1.0187+04 | 287.5822 | 1.0474+04 |
| KG/DAY | 4.0000+04 | 4.0000+04 | 3.9393+04 | 1010.3970 | 4.0404+04 |
| L/DAY | 4.8989+04 | 4.8989+04 | 4.9095+04 | 1215.1292 | 5.8062+04 |
| STATE VARIABLES: | | | | | |
| TEMP C | 141.0000 | 141.0000 | 157.4842 | 90.0000 | 155.7932 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 8.8423-04 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9991 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | 18.4581 | 18.4581 | 2.7036 | -38.7207 | 1.5663 |
| J/KG | 1.0844+05 | 1.0844+05 | 1.6779+04 | -2.6450+05 | 9745.3099 |
| KW | 50.2050 | 50.2050 | 7.6504 | -3.0932 | 4.5572 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -108.6053 | -108.6053 | -100.8350 | -103.0995 | -100.8715 |
| CAL/GM-K | -0.6381 | -0.6381 | -0.6258 | -0.7043 | -0.6276 |
| DENSITY: | | | | | |
| MOL/CC | 4.7970-03 | 4.7970-03 | 4.9799-03 | 5.6800-03 | 4.3296-03 |
| GM/CC | 0.8165 | 0.8165 | 0.8024 | 0.8315 | 0.6959 |
| AVG MW | 170.2108 | 170.2108 | 161.1280 | 146.3925 | 160.7234 |

ETHPLA HOHIN LIQUOR MEOHIN NACIT
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| STREAM ID | ETHPLA | HOHIN | LIQUOR | MEOHIN | NACIT |
|---|---|---|---|---|---|
| FROM : | PLAFLASH | ---- | CRYSTALL | ---- | ---- |
| TO : | B11 | B10 | ---- | B4 | SACCH |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | VAPOR | LIQUID | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 4736.6216 | 4.6347+05 | 5379.6749 | 0.0 | 0.0 |
| GLUCOSE | 32.1588 | 0.0 | 0.0 | 0.0 | 0.0 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|---|---|---|---|---|---|
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 3708.0625 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 9778.5812 | 0.0 | 0.0 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 4.7018+04 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 4.2709-21 | 0.0 | 0.0 | 0.0 | 0.0 |
| COST: | | | | | |
| $/HR | MISSING | MISSING | 0.0 | MISSING | 415.6513 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 1.4547+04 | 4.6347+05 | 5379.6749 | 4.7018+04 | 3708.0625 |
| KG/DAY | 4.2133+04 | 2.0039+05 | 2325.9924 | 3.6158+04 | 5201.0000 |
| L/DAY | 1.5778+07 | 2.6516+05 | 3036.7727 | 4.5600+04 | 6233.4334 |
| STATE VARIABLES: | | | | | |
| TEMP C | 288.0000 | 25.0000 | 5.0000 | 25.0000 | 25.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 0.0 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | 0.5687 | -288.8616 | -290.6010 | -238.3998 | -445.7720 |
| J/KG | 4712.3768 | -1.6034+07 | -1.6131+07 | -7.4402+06 | -7.6275+06 |
| KW | 2.2980 | -3.7189+04 | -434.2608 | -3113.6480 | -459.1529 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -42.6606 | -40.8242 | -42.2666 | -57.3816 | -31.0800 |
| CAL/GM-K | -0.3535 | -2.2661 | -2.3462 | -1.7908 | -0.5318 |
| DENSITY: | | | | | |
| MOL/CC | 2.2128-05 | 4.1949-02 | 4.2516-02 | 2.4746-02 | 1.4277-02 |
| GM/CC | 2.6703-03 | 0.7557 | 0.7659 | 0.7929 | 0.8344 |
| AVG MW | 120.6779 | 18.0153 | 18.0153 | 32.0422 | 58.4425 |

NH3 PLA PLA1 PLAOUT PLAREC
--------------------------

| STREAM ID | NH3 | PLA | PLA1 | PLAOUT | PLAREC |
|---|---|---|---|---|---|
| FROM : | ---- | PLAFLASH | POLYREAC | B4 | DRYPLA |
| TO : | AAS | CHLMIX | B19 | ---- | POLYREAC |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | MIXED | LIQUID | MIXED | MISSING | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 4.9941+04 | 4.4330-02 | 9474.2927 | 0.0 | 2423.0262 |
| GLUCOSE | 0.0 | 1.8696-02 | 64.3546 | 0.0 | 32.1773 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AMMONIA | 9983.5910 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 2.6769 | 1.9565+04 | 0.0 | 9773.5421 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 5.6034 | 11.2064 | 5.6034 | 5.6032 |
| COST: | | | | | |
| $/HR | 374.8750 | MISSING | MISSING | MISSING | MISSING |
| TOTAL FLOW: | | | | | |
| MOL/HR | 5.9925+04 | 8.3433 | 2.9115+04 | 5.6034 | 1.2234+04 |
| KG/DAY | 2.9990+04 | 1.0671+04 | 1.0562+05 | 1.0660+04 | 5.1772+04 |
| L/DAY | 5.5321+06 | 658.4520 | 8.1744+06 | 1.0660+07 | 5.0623+04 |
| STATE VARIABLES: | | | | | |
| TEMP C | 25.0000 | 288.0000 | 170.0000 | 25.8549 | 99.8609 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.1705 | 0.0 | 0.3202 | MISSING | 0.0 |
| LFRAC | 0.8295 | 1.0000 | 0.6798 | MISSING | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | MISSING | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -301.7511 | -365.5821 | -60.5489 | MISSING | -50.9332 |
| J/KG | -1.4471+07 | -6859.8799 | -4.0058+05 | MISSING | -2.8887+05 |
| KW | -5022.8586 | -0.8473 | -489.6922 | MISSING | -173.0928 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -82.8665 | -204.9916 | -71.9658 | MISSING | -98.0774 |
| CAL/GM-K | -3.9739 | -3.8465-03 | -0.4761 | MISSING | -0.5562 |
| DENSITY: | | | | | |
| MOL/CC | 2.5997-04 | 3.0411-04 | 8.5482-05 | MISSING | 5.8003-03 |
| GM/CC | 5.4211-03 | 16.2066 | 1.2921-02 | MISSING | 1.0227 |
| AVG MW | 20.8526 | 5.3293+04 | 151.1527 | 7.9270+04 | 176.3216 |

PLASUGAR PREC-PLA PREC-XYL PROD-C PROD-H
----------------------------------------

| STREAM ID | PLASUGAR | PREC-PLA | PREC-XYL | PROD-C | PROD-H |
|---|---|---|---|---|---|
| FROM : | FUGEPLA | FUGEPLA | FUGEXYL | B20 | SA-HYDRO |
| TO : | B15 | ---- | ---- | FILTER | B20 |
| CONV. MAX. REL. ERR: | 0.0 | 0.0 | 0.0 | 0.0 | -3.3165-07 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | MIXED | LIQUID | MIXED | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 8.1648+05 | 4.2973+04 | 5944.0484 | 1.0532+06 | 1.0532+06 |
| GLUCOSE | 3539.5017 | 0.0 | 0.0 | 4.2792 | 4.2792 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 3593.8629 | 3593.8629 |
| AMMONIA | 0.0 | 9983.5910 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 6.2002+04 | 6.2002+04 |
| H2SO4 | 0.0 | 0.0 | 32.9029 | 573.9393 | 573.9393 |
| CAOH2 | 0.0 | 0.0 | 28.4756 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 541.0364 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 4695.8931 | 0.0 | 4781.4643 | 4781.4643 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 3539.4104 | 3539.4104 |
| ENZ/XYL | 0.0 | 4291.6202 | 0.0 | 0.1088 | 0.1088 |
| NACIT | 0.0 | 3708.0625 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 0.0 | 4.7259-05 | 4.7259-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| COST: | | | | | |
| $/HR | MISSING | 0.0 | 0.0 | MISSING | MISSING |
| TOTAL FLOW: | | | | | |
| MOL/HR | 8.2002+05 | 6.5652+04 | 6546.4633 | 1.1277+06 | 1.1277+06 |
| KG/DAY | 3.6832+05 | 5.1683+04 | 4465.8765 | 5.1868+05 | 5.1868+05 |
| L/DAY | 4.7736+05 | 5.5182+06 | 7901.4840 | 1.8739+07 | 9.2638+08 |
| STATE VARIABLES: | | | | | |
| TEMP C | 25.0000 | 25.0000 | 25.0000 | 102.7762 | 150.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.1548 | 0.0 | 2.1796-02 | 0.9917 |
| LFRAC | 1.0000 | 0.8452 | 1.0000 | 0.9782 | 8.3049-03 |

| | | | | | |
|---|---|---|---|---|---|
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -293.1794 | -350.6459 | -388.8234 | -286.5859 | -243.3661 |
| J/KG | -1.5665+07 | -1.0690+07 | -1.3679+07 | -1.4954+07 | -1.2698+07 |
| KW | -6.6781+04 | -6394.5912 | -707.0605 | -8.9770+04 | -7.6232+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -41.8127 | -90.8295 | -130.1125 | -36.2300 | -8.8748 |
| CAL/GM-K | -2.2342 | -2.7691 | -4.5775 | -1.8904 | -0.4631 |
| DENSITY: | | | | | |
| MOL/CC | 4.1228-02 | 2.8553-04 | 1.9884-02 | 1.4442-03 | 2.9215-05 |
| GM/CC | 0.7716 | 9.3658-03 | 0.5652 | 2.7679-02 | 5.5990-04 |
| AVG MW | 18.7151 | 32.8010 | 28.4242 | 19.1651 | 19.1651 |

PURE PURGE RECYCLE S1 S10
-------------------------

| STREAM ID | PURE | PURGE | RECYCLE | S1 | S10 |
|---|---|---|---|---|---|
| FROM : | B25 | SPLIT | SPLIT | B3 | B5 |
| TO : | B2 | ---- | B22 | B2 | B8 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | VAPOR | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 887.7925 | 1.0760+04 | 1.0760+04 | 6440.5528 | 3.5305+05 |
| GLUCOSE | 32.1773 | 0.0 | 0.0 | 5.8179-03 | 0.0 |
| XYLOSE | 0.0 | 244.3500 | 244.3500 | 0.0 | 2.3098-02 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 85.5712 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 5.5705-04 |
| ENZ/XYL | 0.0 | 238.6606 | 238.6606 | 0.0 | 0.1081 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 6163.4740 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 9791.7798 | 0.0 | 0.0 | 242.5760 | 4.7257-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 9.5277-24 | 0.0 |
| COST: | | | | | |
| $/HR | 0.0 | MISSING | MISSING | MISSING | MISSING |
| TOTAL FLOW: | | | | | |
| MOL/HR | 1.6875+04 | 1.1243+04 | 1.1243+04 | 6683.1346 | 3.5313+05 |
| KG/DAY | 5.3848+04 | 6404.0166 | 6404.0166 | 3775.6430 | 1.5272+05 |
| L/DAY | 6.0688+04 | 7988.6620 | 7988.6620 | 5.4081+06 | 2.2363+08 |
| STATE VARIABLES: | | | | | |
| TEMP C | 22.0031 | 95.0000 | 95.0000 | 140.8396 | 102.4610 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 1.0000 | 0.8632 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 0.0 | 0.1368 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -278.3628 | -313.6615 | -313.6615 | -226.5644 | -245.1113 |
| J/KG | -2.0937+06 | -1.3216+07 | -1.3216+07 | -9.6248+06 | -1.3603+07 |
| KW | -1304.8427 | -979.5516 | -979.5516 | -420.6000 | -2.4043+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -271.1606 | -43.2539 | -43.2539 | -10.3718 | -12.5048 |
| CAL/GM-K | -2.0395 | -1.8224 | -1.8224 | -0.4406 | -0.6940 |
| DENSITY: | | | | | |
| MOL/CC | 6.6736-03 | 3.3776-02 | 3.3776-02 | 2.9658-05 | 3.7898-05 |
| GM/CC | 0.8873 | 0.8016 | 0.8016 | 6.9815-04 | 6.8290-04 |
| AVG MW | 132.9556 | 23.7341 | 23.7341 | 23.5396 | 18.0192 |

S11 S12 S13 S14 S15
-------------------

| STREAM ID | S11 | S12 | S13 | S14 | S15 |
|---|---|---|---|---|---|
| FROM : | B8 | PSPLIT | B11 | B11 | B8 |
| TO : | SA-HYDRO | B11 | B17 | ETHFLASH | B13 |
| CONV. MAX. REL. ERR: | 0.0 | 0.0 | 0.0 | 0.0 | -7.7978-11 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | MIXED | MIXED | MIXED | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 2312.8515 | 4736.9972 | 4736.9972 | 4736.6216 | 3.5305+05 |
| GLUCOSE | 0.0 | 32.1773 | 32.1773 | 32.1588 | 0.0 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 2.3098-02 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 573.9393 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 85.5712 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 5.5705-04 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 0.1081 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 9782.1932 | 9782.1932 | 9778.5812 | 4.7257-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 5.6032 | 5.6032 | 4.2709-21 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 2886.7907 | 1.4557+04 | 1.4557+04 | 1.4547+04 | 3.5313+05 |
| KG/DAY | 2351.0000 | 5.2808+04 | 5.2808+04 | 4.2133+04 | 1.5272+05 |
| L/DAY | 2974.8273 | 2.2712+06 | 1.1769+07 | 4.4220+06 | 2.2326+08 |
| STATE VARIABLES: | | | | | |
| TEMP C | 92.0000 | 110.0002 | 237.4785 | 180.0000 | 102.4609 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.2038 | 0.8207 | 0.3396 | 0.8618 |
| LFRAC | 1.0000 | 0.7962 | 0.1793 | 0.6604 | 0.1382 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -393.7318 | -77.4762 | -19.6443 | -57.3015 | -245.1722 |
| J/KG | -1.1603+07 | -5.1257+05 | -1.2996+05 | -4.7483+05 | -1.3606+07 |
| KW | -315.7282 | -313.2832 | -79.4337 | -231.5515 | -2.4049+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -49.1532 | -81.7670 | -51.8530 | -70.2409 | -12.5436 |
| CAL/GM-K | -1.4485 | -0.5410 | -0.3430 | -0.5821 | -0.6961 |
| DENSITY: | | | | | |
| MOL/CC | 2.3290-02 | 1.5383-04 | 2.9684-05 | 7.8954-05 | 3.7961-05 |
| GM/CC | 0.7903 | 2.3252-02 | 4.4869-03 | 9.5280-03 | 6.8403-04 |
| AVG MW | 33.9333 | 151.1537 | 151.1537 | 120.6779 | 18.0192 |

S16 S17 S18 S19 S2
------------------

| STREAM ID | S16 | S17 | S18 | S19 | S2 |
|---|---|---|---|---|---|
| FROM : | B9 | B9 | CHROMA | B10 | B5 |
| TO : | LLE | ---- | ---- | B21 | WASH |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 8.1648+05 | 0.0 | 0.0 | 8.2291+05 | 8.2291+05 |
| GLUCOSE | 32.1773 | 0.0 | 0.0 | 5.8149-03 | 5.8149-03 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 2.3098-02 | 2.3098-02 |

| | | | | | |
|---|---|---|---|---|---|
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 6.2002+04 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 1704.2599 | 0.0 | 85.5711 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 5.5705-04 | 5.5705-04 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.1081 | 0.1081 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 6371.1031 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 0.0 | 4.5375-05 | 4.5375-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 8.2288+05 | 1704.2599 | 6.2002+04 | 8.2300+05 | 8.2292+05 |
| KG/DAY | 3.6693+05 | 1391.2766 | 2.9802+04 | 3.5587+05 | 3.5580+05 |
| L/DAY | 4.8678+05 | 1100.1266 | 3.6081+04 | 4.8299+05 | 4.9848+05 |
| STATE VARIABLES: | | | | | |
| TEMP C | 37.0000 | 37.0000 | 32.0000 | 58.8310 | 95.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -290.8789 | -190.8871 | -296.3694 | -285.9187 | -282.7809 |
| J/KG | -1.5656+07 | -5.6119+06 | -1.4798+07 | -1.5869+07 | -1.5697+07 |
| KW | -6.6489+04 | -90.3670 | -5104.3229 | -6.5364+04 | -6.4640+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -43.6981 | -55.7109 | -41.8349 | -38.5982 | -36.4492 |
| CAL/GM-K | -2.3519 | -1.6378 | -2.0889 | -2.1423 | -2.0232 |
| DENSITY: | | | | | |
| MOL/CC | 4.0571-02 | 3.7180-02 | 4.1242-02 | 4.0895-02 | 3.9621-02 |
| GM/CC | 0.7538 | 1.2647 | 0.8260 | 0.7368 | 0.7138 |
| AVG MW | 18.5796 | 34.0147 | 20.0274 | 18.0170 | 18.0153 |

S20 S21 S22 S23 S24
-------------------

| STREAM ID | S20 | S21 | S22 | S23 | S24 |
|---|---|---|---|---|---|
| FROM : | CHROMA | B15 | B13 | B16 | B17 |
| TO : | EVAP | PLA-FERM | B10 | XLAFERM | PLAFLASH |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 3.0202+05 | 8.1648+05 | 3.5305+05 | 3.0202+05 | 4736.6659 |
| GLUCOSE | 0.0 | 3539.5017 | 0.0 | 4.2792 | 32.1775 |
| XYLOSE | 488.7400 | 0.0 | 2.3098-02 | 3838.2129 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 6.2002+04 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 85.5711 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 5.5705-04 | 0.0 | 0.0 |
| ENZ/XYL | 3182.3591 | 0.0 | 0.1081 | 238.6606 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 3.4511-05 | 0.0 | 9781.2581 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 5.6034 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 3.0569+05 | 8.2002+05 | 3.5313+05 | 3.6810+05 | 1.4556+04 |
| KG/DAY | 1.4396+05 | 3.6832+05 | 1.5272+05 | 1.7510+05 | 5.2804+04 |
| L/DAY | 1.8500+05 | 4.8146+05 | 2.1546+05 | 2.2110+05 | 1.5779+07 |
| STATE VARIABLES: | | | | | |
| TEMP C | 32.0000 | 37.0000 | 102.4441 | 32.0000 | 288.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.9994 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 5.7320-04 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -297.0912 | -292.1135 | -282.1051 | -297.5477 | 0.3588 |
| J/KG | -1.5140+07 | -1.5608+07 | -1.5656+07 | -1.5012+07 | 2373.7262 |
| KW | -2.5227+04 | -6.6539+04 | -2.7672+04 | -3.0424+04 | 1.4507 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -42.2578 | -40.9755 | -36.0294 | -41.5442 | -42.7536 |
| CAL/GM-K | -2.1535 | -2.1894 | -1.9995 | -2.0960 | -0.2828 |
| DENSITY: | | | | | |
| MOL/CC | 3.9657-02 | 4.0877-02 | 3.9336-02 | 3.9957-02 | 2.2139-05 |
| GM/CC | 0.7782 | 0.7650 | 0.7088 | 0.7920 | 3.3465-03 |
| AVG MW | 19.6229 | 18.7151 | 18.0192 | 19.8206 | 151.1560 |

S25 S26 S27 S28 S29
-------------------

| STREAM ID | S25 | S26 | S27 | S28 | S29 |
|---|---|---|---|---|---|
| FROM : | B22 | B20 | B12 | B12 | B21 |
| TO : | B16 | B1 | ---- | CHROMA | B5 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | MIXED | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 3.0202+05 | 1.0509+06 | 0.0 | 3.0202+05 | 8.2291+05 |
| GLUCOSE | 4.2792 | 4.1938 | 0.0 | 0.0 | 5.8149-03 |
| XYLOSE | 3838.2129 | 2.3109-02 | 0.0 | 488.7400 | 2.3098-02 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 6.2002+04 | 0.0 | 0.0 | 6.2002+04 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 1639.1820 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 1.4330+04 | 0.0 | 0.0 | 5.5705-04 |
| ENZ/XYL | 238.6606 | 0.1082 | 0.0 | 3182.3591 | 0.1081 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 3.1610-05 | 0.0 | 0.0 | 4.5375-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 3.6810+05 | 1.0652+06 | 1639.1820 | 3.6769+05 | 8.2292+05 |
| KG/DAY | 1.7510+05 | 5.1633+05 | 1338.1500 | 1.7377+05 | 3.5580+05 |
| L/DAY | 2.2035+05 | 8.4619+08 | 1055.1884 | 2.2108+05 | 4.8293+05 |
| STATE VARIABLES: | | | | | |
| TEMP C | 27.2171 | 140.0000 | 32.0000 | 32.0000 | 58.8310 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.9826 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 1.7439-02 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -297.9740 | -251.2037 | -191.3770 | -296.9659 | -285.9288 |
| J/KG | -1.5034+07 | -1.2438+07 | -5.6263+06 | -1.5081+07 | -1.5871+07 |
| KW | -3.0468+04 | -7.4328+04 | -87.1394 | -3.0331+04 | -6.5360+04 |

| | | | | | |
|---|---|---|---|---|---|
| ENTROPY: | | | | | |
| CAL/MOL-K | -41.8805 | -11.3258 | -56.0912 | -41.2836 | -38.5986 |
| CAL/GM-K | -2.1130 | -0.5608 | -1.6490 | -2.0966 | -2.1425 |
| DENSITY: | | | | | |
| MOL/CC | 4.0092-02 | 3.0211-05 | 3.7283-02 | 3.9915-02 | 4.0896-02 |
| GM/CC | 0.7946 | 6.1018-04 | 1.2682 | 0.7860 | 0.7367 |
| AVG MW | 19.8206 | 20.1972 | 34.0147 | 19.6911 | 18.0153 |

S3 S30 S31 S32 S33
------------------

| STREAM ID | S3 | S30 | S31 | S32 | S33 |
|---|---|---|---|---|---|
| FROM : | POLYHEAT | B21 | LLE | LLEREC | LLE |
| TO : | POLYREAC | ---- | LLEREC | B25 | B25 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 887.7925 | 0.0 | 8.1559+05 | 0.0 | 887.7925 |
| GLUCOSE | 32.1773 | 0.0 | 32.1768 | 32.1768 | 5.0133-04 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 85.5711 | 0.0 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 6163.4740 | 0.0 | 4152.5822 | 3944.9531 | 2218.5209 |
| DIETHER | 9791.7798 | 0.0 | 5.3221-08 | 5.3221-08 | 9791.7798 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 1.6875+04 | 85.5711 | 8.1978+05 | 3977.1299 | 1.2898+04 |
| KG/DAY | 5.3848+04 | 69.8562 | 3.6175+05 | 8667.6887 | 4.5180+04 |
| L/DAY | 6.6764+04 | 55.9439 | 4.7597+05 | 9147.5599 | 5.1873+04 |
| STATE VARIABLES: | | | | | |
| TEMP C | 170.0000 | 58.8310 | 22.7000 | 22.7000 | 34.5000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -241.7789 | -188.7454 | -291.0845 | -709.1282 | -145.5361 |
| J/KG | -1.8185+06 | -5.5489+06 | -1.5831+07 | -7.8091+06 | -9.9715+05 |
| KW | -1133.3538 | -4.4864 | -6.6285+04 | -783.4153 | -521.4274 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -247.3708 | -54.1170 | -43.4061 | -536.0210 | -189.3347 |
| CAL/GM-K | -1.8606 | -1.5910 | -2.3607 | -5.9028 | -1.2972 |
| DENSITY: | | | | | |
| MOL/CC | 6.0662-03 | 3.6710-02 | 4.1336-02 | 1.0435-02 | 5.9676-03 |
| GM/CC | 0.8065 | 1.2487 | 0.7600 | 0.9475 | 0.8710 |
| AVG MW | 132.9556 | 34.0147 | 18.3867 | 90.8076 | 145.9520 |

S34 S36 S4 S5 S6
----------------

| STREAM ID | S34 | S36 | S4 | S5 | S6 |
|---|---|---|---|---|---|
| FROM : | B23 | B23 | B19 | FILTER | B6 |
| TO : | COOL2 | SPLIT | PSPLIT | EVAP2 | B5 |
| CONV. MAX. REL. ERR: | 0.0 | 0.0 | -1.0331-07 | 0.0 | 0.0 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | MIXED | MIXED | VAPOR |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 2.6898+04 | 2.1519+04 | 9474.2927 | 7.7179+05 | 3.5305+05 |
| GLUCOSE | 0.0 | 0.0 | 64.3546 | 0.0 | 0.0 |
| XYLOSE | 488.6902 | 488.7000 | 0.0 | 0.0 | 2.3098-02 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 4781.4643 | 85.5712 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 3539.4104 | 5.5705-04 |
| ENZ/XYL | 3182.0769 | 477.3211 | 0.0 | 0.1088 | 0.1081 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 0.0 | 0.0 | 1.9565+04 | 4.7259-05 | 4.7257-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 0.0 | 11.2064 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 3.0569+04 | 2.2485+04 | 2.9115+04 | 7.8012+05 | 3.5313+05 |
| KG/DAY | 2.5010+04 | 1.2808+04 | 1.0562+05 | 3.5291+05 | 1.5272+05 |
| L/DAY | 2.6881+04 | 1.5977+04 | 4.5424+06 | 1.4961+08 | 2.8909+08 |
| STATE VARIABLES: | | | | | |
| TEMP C | 45.9187 | 95.0000 | 110.0000 | 102.7762 | 145.1174 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.2038 | 0.2606 | 1.0000 |
| LFRAC | 1.0000 | 1.0000 | 0.7962 | 0.7394 | 0.0 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -376.6121 | -313.6615 | -77.4753 | -274.5095 | -237.7758 |
| J/KG | -1.1048+07 | -1.3216+07 | -5.1256+05 | -1.4564+07 | -1.3196+07 |
| KW | -3197.9744 | -1959.1032 | -626.5854 | -5.9486+04 | -2.3324+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -59.5963 | -43.2539 | -81.7674 | -29.8486 | -7.8899 |
| CAL/GM-K | -1.7482 | -1.8224 | -0.5410 | -1.5836 | -0.4379 |
| DENSITY: | | | | | |
| MOL/CC | 2.7293-02 | 3.3776-02 | 1.5383-04 | 1.2514-04 | 2.9316-05 |
| GM/CC | 0.9304 | 0.8016 | 2.3252-02 | 2.3588-03 | 5.2826-04 |
| AVG MW | 34.0897 | 23.7341 | 151.1527 | 18.8490 | 18.0192 |

S7 S8 S9 SA-IN SACHIN
---------------------

| STREAM ID | S7 | S8 | S9 | SA-IN | SACHIN |
|---|---|---|---|---|---|
| FROM : | CHLMIX | B4 | PSPLIT | ---- | WASH2 |
| TO : | B4 | B18 | DRYPLA | B8 | SACCH |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | LIQUID | LIQUID | MIXED | LIQUID | MIXED |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 4.4330-02 | 4.4330-02 | 4736.9972 | 2312.8515 | 8.5945+05 |
| GLUCOSE | 1.8696-02 | 1.8696-02 | 32.1773 | 0.0 | 0.0 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 9983.5910 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 3.1840+04 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 573.9393 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 0.0 | 0.0 | 4695.8931 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | | |
|---|---|---|---|---|---|
| ENZ/XYL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 2.6769 | 2.6769 | 9782.1932 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 4.7018+04 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 3.9247+04 | 3.9247+04 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 5.6034 | 0.0 | 5.6032 | 0.0 | 0.0 |
| COST: | | | | | |
| $/HR | MISSING | MISSING | MISSING | 26.9951 | MISSING |
| TOTAL FLOW: | | | | | |
| MOL/HR | 3.9255+04 | 8.6268+04 | 1.4557+04 | 2886.7907 | 9.0597+05 |
| KG/DAY | 9.0671+04 | 1.1617+05 | 5.2808+04 | 2351.0000 | 3.9913+05 |
| L/DAY | 7.0816+04 | 1.0504+05 | 2.2712+06 | 2857.2687 | 8.5159+06 |
| STATE VARIABLES: | | | | | |
| TEMP C | 24.1064 | 25.8549 | 110.0002 | 25.0000 | 64.7913 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 0.0 | 0.0 | 0.2038 | 0.0 | 1.3854-02 |
| LFRAC | 1.0000 | 1.0000 | 0.7962 | 1.0000 | 0.9861 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -124.3836 | -186.5084 | -77.4762 | -401.1851 | -285.9382 |
| J/KG | -1.2924+06 | -3.3241+06 | -5.1257+05 | -1.1823+07 | -1.5577+07 |
| KW | -1356.3103 | -4469.3582 | -313.2832 | -321.7049 | -7.1959+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -43.2611 | -49.6021 | -81.7670 | -54.5391 | -40.6996 |
| CAL/GM-K | -0.4495 | -0.8840 | -0.5410 | -1.6072 | -2.2172 |
| DENSITY: | | | | | |
| MOL/CC | 1.3304-02 | 1.9710-02 | 1.5383-04 | 2.4248-02 | 2.5533-03 |
| GM/CC | 1.2804 | 1.1059 | 2.3252-02 | 0.8228 | 4.6869-02 |
| AVG MW | 96.2410 | 56.1084 | 151.1537 | 33.9333 | 18.3566 |

STEAM1 STEAM2 STEAM3 STEAM4 STEAM5
----------------------------------

| STREAM ID | STEAM1 | STEAM2 | STEAM3 | STEAM4 | STEAM5 |
|---|---|---|---|---|---|
| FROM : | ETHFLASH | DRYPLA | EVAP2 | EVAP | B19 |
| TO : | B3 | B3 | B6 | B19 | B6 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | VAPOR | VAPOR | VAPOR | VAPOR | VAPOR |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 4126.5819 | 2313.9709 | 7.7926+04 | 2.7512+05 | 2.7512+05 |
| GLUCOSE | 5.8074-03 | 1.0454-05 | 0.0 | 0.0 | 0.0 |
| XYLOSE | 0.0 | 0.0 | 0.0 | 2.3098-02 | 2.3098-02 |
| AMMONIA | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 0.0 | 85.5712 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 5.5705-04 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 0.0 | 3.5645-07 | 0.1081 | 0.1081 |
| NACIT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| DIETHER | 233.9249 | 8.6511 | 4.7257-05 | 0.0 | 0.0 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 0.0 | 9.5277-24 | 0.0 | 0.0 | 0.0 |
| COST: | | | | | |
| $/HR | MISSING | MISSING | 0.0 | 0.0 | MISSING |
| TOTAL FLOW: | | | | | |
| MOL/HR | 4360.5126 | 2322.6220 | 7.8012+04 | 2.7512+05 | 2.7512+05 |
| KG/DAY | 2739.8187 | 1035.8243 | 3.3762+04 | 1.1895+05 | 1.1895+05 |
| L/DAY | 3.6715+06 | 1.6915+06 | 4.4841+07 | 2.0228+08 | 2.3075+08 |
| STATE VARIABLES: | | | | | |
| TEMP C | 157.4842 | 99.8609 | 110.0000 | 103.3036 | 155.2010 |
| PRES ATM | 1.0000 | 1.0000 | 1.2993 | 1.0000 | 1.0000 |
| VFRAC | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| LFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -220.3544 | -238.2231 | -238.9171 | -239.2434 | -237.4522 |
| J/KG | -8.4168+06 | -1.2820+07 | -1.3249+07 | -1.3280+07 | -1.3181+07 |
| KW | -266.9050 | -153.6951 | -5177.3053 | -1.8284+04 | -1.8147+04 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -11.1250 | -9.0810 | -9.1396 | -8.7585 | -7.6939 |
| CAL/GM-K | -0.4249 | -0.4887 | -0.5068 | -0.4862 | -0.4271 |
| DENSITY: | | | | | |
| MOL/CC | 2.8504-05 | 3.2956-05 | 4.1753-05 | 3.2642-05 | 2.8615-05 |
| GM/CC | 7.4623-04 | 6.1239-04 | 7.5293-04 | 5.8806-04 | 5.1550-04 |
| AVG MW | 26.1802 | 18.5822 | 18.0328 | 18.0153 | 18.0153 |

STOUT SUGARSP SUGARSX WASTE WATER1
----------------------------------

| STREAM ID | STOUT | SUGARSP | SUGARSX | WASTE | WATER1 |
|---|---|---|---|---|---|
| FROM : | B2 | SACCH | CAOH-NEU | LLEREC | WATPUR |
| TO : | WATPUR | FUGEPLA | FUGEXYL | ---- | B10 |
| SUBSTREAM: MIXED | | | | | |
| PHASE: | MIXED | MIXED | LIQUID | LIQUID | LIQUID |
| COMPONENTS: MOL/HR | | | | | |
| WATER | 6440.5528 | 8.5945+05 | 2.9720+05 | 8.1559+05 | 6395.5466 |
| GLUCOSE | 5.8179-03 | 3539.5017 | 4.2792 | 0.0 | 5.8149-03 |
| XYLOSE | 0.0 | 0.0 | 3593.8629 | 0.0 | 0.0 |
| AMMONIA | 0.0 | 9983.5910 | 0.0 | 0.0 | 0.0 |
| OTHLIQUI | 0.0 | 0.0 | 6.2002+04 | 0.0 | 0.0 |
| H2SO4 | 0.0 | 0.0 | 32.9029 | 0.0 | 0.0 |
| CAOH2 | 0.0 | 0.0 | 28.4756 | 0.0 | 0.0 |
| CASO4 | 0.0 | 0.0 | 541.0364 | 0.0 | 0.0 |
| OTHSOLID | 0.0 | 4695.8931 | 0.0 | 0.0 | 0.0 |
| CELLULOS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENZ/XYL | 0.0 | 4291.6202 | 0.0 | 0.0 | 0.0 |
| NACIT | 0.0 | 3708.0625 | 0.0 | 0.0 | 0.0 |
| LACTICAC | 0.0 | 0.0 | 0.0 | 207.6291 | 0.0 |
| DIETHER | 242.5760 | 0.0 | 0.0 | 0.0 | 1.0864-05 |
| N2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| METHANOL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CH2CL2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ETHYL-01 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PLA | 9.5277-24 | 0.0 | 0.0 | 0.0 | 0.0 |
| TOTAL FLOW: | | | | | |
| MOL/HR | 6683.1346 | 8.8567+05 | 3.6341+05 | 8.1580+05 | 6395.5524 |
| KG/DAY | 3775.6430 | 4.2001+05 | 1.7317+05 | 3.5308+05 | 2765.2467 |
| L/DAY | 4.4087+05 | 6.0247+06 | 2.2045+05 | 4.6637+05 | 3855.9400 |
| STATE VARIABLES: | | | | | |
| TEMP C | 90.0000 | 25.0000 | 25.0000 | 22.7000 | 90.0000 |
| PRES ATM | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| VFRAC | 9.4773-02 | 1.1531-02 | 0.0 | 0.0 | 0.0 |
| LFRAC | 0.9052 | 0.9885 | 1.0000 | 1.0000 | 1.0000 |
| SFRAC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ENTHALPY: | | | | | |
| KJ/MOL | -268.0753 | -297.4390 | -298.9470 | -289.1608 | -283.2188 |
| J/KG | -1.1388+07 | -1.5053+07 | -1.5057+07 | -1.6035+07 | -1.5721+07 |
| KW | -497.6620 | -7.3176+04 | -3.0177+04 | -6.5527+04 | -503.1501 |
| ENTROPY: | | | | | |
| CAL/MOL-K | -36.9156 | -45.3638 | -43.3553 | -41.1044 | -36.7348 |
| CAL/GM-K | -1.5682 | -2.2958 | -2.1836 | -2.2793 | -2.0391 |

```
DENSITY:
  MOL/CC              3.6382-04  3.5282-03  3.9564-02  4.1982-02  3.9807-02
  GM/CC               8.5641-03  6.9714-02     0.7855     0.7571     0.7171
AVG MW                  23.5396    19.7593    19.8545    18.0336    18.0154

WETBSGC WETBSGH X1 X2 XYLITOL
-----------------------------

STREAM ID               WETBSGC    WETBSGH    X1         X2         XYLITOL
FROM :                  WASH       B1         B18        B18        CRYSTALL
TO   :                  B20        SA-HYDRO   ----       ----       ----

SUBSTREAM: MIXED
PHASE:                  LIQUID     MIXED      LIQUID     LIQUID     LIQUID
COMPONENTS: MOL/HR
  WATER               1.0509+06  1.0509+06  4.2623-02  1.7063-03     0.0
  GLUCOSE                4.1938     4.1938  1.8696-02  7.6413-08     0.0
  XYLOSE              2.3109-02  2.3109-02     0.0        0.0        0.0
  AMMONIA                0.0        0.0        0.0        0.0        0.0
  OTHLIQUI               0.0        0.0        0.0        0.0        0.0
  H2SO4                  0.0        0.0        0.0        0.0        0.0
  CAOH2                  0.0        0.0        0.0        0.0        0.0
  CASO4                  0.0        0.0        0.0        0.0        0.0
  OTHSOLID               0.0        0.0        0.0        0.0        0.0
  CELLULOS            1.4330+04  1.4330+04     0.0        0.0        0.0
  ENZ/XYL                0.1082     0.1082     0.0        0.0     2704.7653
  NACIT                  0.0        0.0        0.0        0.0        0.0
  LACTICAC               0.0        0.0        0.0        0.0        0.0
  DIETHER             3.1610-05  3.1610-05     2.6769  1.0941-05     0.0
  N2                     0.0        0.0        0.0        0.0        0.0
  METHANOL               0.0        0.0     4.6971+04    47.0182     0.0
  CH2CL2                 0.0        0.0     1.6256+04  2.2991+04     0.0
  ETHYL-01               0.0        0.0        0.0        0.0        0.0
  PLA                    0.0        0.0        0.0        0.0        0.0
COST:
  $/HR                  MISSING    MISSING    MISSING    MISSING   589.7120
TOTAL FLOW:
  MOL/HR              1.0652+06  1.0652+06  6.3230+04  2.3038+04  2704.7653
  KG/DAY              5.1633+05  5.1633+05  6.9268+04  4.6900+04  9876.5445
  L/DAY               6.7532+05  8.6802+08  9.2960+04  4.2010+04  7977.8692
STATE VARIABLES:
  TEMP   C              75.9008   150.0000    55.1613    40.1463     5.0000
  PRES   ATM             1.0000     1.0000     1.0000     1.0000     1.0000
  VFRAC                  0.0        0.9837     0.0        0.0        0.0
  LFRAC                  1.0000  1.6327-02     1.0000     1.0000     1.0000
  SFRAC                  0.0        0.0        0.0        0.0        0.0
ENTHALPY:
  KJ/MOL              -296.9584  -250.7606  -208.1253  -123.1558 -1068.0635
  J/KG               -1.4703+07 -1.2416+07 -4.5596+06 -1.4519+06 -7.0199+06
  KW                 -8.7866+04 -7.4197+04 -3655.4916  -788.1246  -802.4614
ENTROPY:
  CAL/MOL-K            -40.3760   -11.0727   -51.9384   -42.1090  -232.0061
  CAL/GM-K              -1.9991    -0.5482    -1.1379    -0.4964    -1.5249
DENSITY:
  MOL/CC              3.7855-02  2.9452-05  1.6325-02  1.3162-02  8.1368-03
  GM/CC                  0.7646  5.9484-04     0.7451     1.1164     1.2380
AVG MW                  20.1972    20.1972    45.6458    84.8243   152.1473

XYLSUGAR XYSUGARS
-----------------

STREAM ID               XYLSUGAR   XYSUGARS
FROM :                  FUGEXYL    FILTER
TO   :                  B22        CAOH-NEU

SUBSTREAM: MIXED
PHASE:                  LIQUID     LIQUID
COMPONENTS: MOL/HR
  WATER               2.9126+05  2.8137+05
  GLUCOSE                4.2792     4.2792
  XYLOSE              3593.8629  3593.8629
  AMMONIA                0.0        0.0
  OTHLIQUI            6.2002+04  6.2002+04
  H2SO4                  0.0      573.9393
  CAOH2                  0.0        0.0
  CASO4                  0.0        0.0
  OTHSOLID               0.0        0.0
  CELLULOS               0.0        0.0
  ENZ/XYL                0.0        0.0
  NACIT                  0.0        0.0
  LACTICAC               0.0        0.0
  DIETHER                0.0        0.0
  N2                     0.0        0.0
  METHANOL               0.0        0.0
  CH2CL2                 0.0        0.0
  ETHYL-01               0.0        0.0
  PLA                    0.0        0.0
TOTAL FLOW:
  MOL/HR              3.5686+05  3.4755+05
  KG/DAY              1.6870+05  1.6578+05
  L/DAY               2.1244+05  2.2204+05
STATE VARIABLES:
  TEMP   C              25.0000   102.7762
  PRES   ATM             1.0000     1.0000
  VFRAC                  0.0        0.0
  LFRAC                  1.0000     1.0000
  SFRAC                  0.0        0.0
ENTHALPY:
  KJ/MOL              -297.4797  -291.6674
  J/KG               -1.5103+07 -1.4675+07
  KW                 -2.9488+04 -2.8158+04
ENTROPY:
  CAL/MOL-K            -41.8685   -37.0445
  CAL/GM-K              -2.1256    -1.8639
DENSITY:
  MOL/CC              4.0315-02  3.7566-02
  GM/CC                  0.7941     0.7466
AVG MW                  19.6973    19.8746

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------    ------------
AASWAT                              7.2647-04    $/L                    2.0027
BSG                                    0.0       $/KG                   0.0
CAOH                                   0.1760    $/KG                  54.1832
ENZYMES                                0.5070    $/KG                 331.0499
LIQUOR                                 0.0       $/KG                   0.0
NACIT                                  1.9180    $/KG                 415.6513
NH3                                    0.3000    $/KG                 374.8750
PREC-PLA                               0.0       $/KG                   0.0
PREC-XYL                               0.0       $/KG                   0.0
PURE                                   0.0       $/KG                   0.0
SA-IN                                  0.2756    $/KG                  26.9951
STEAM3                                 0.0       $/KG                   0.0
STEAM4                                 0.0       $/KG                   0.0
XYLITOL                                1.4330    $/KG                 589.7120

1
-
```

```
STREAM ID               1
FROM :                  PLA-FERM
TO   :                  B9

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               8.1648+05
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID            1704.2599
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC            6371.1031
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              8.2459+05
  KG/DAY              3.6832+05
  L/DAY               4.8787+05
STATE VARIABLES:
  TEMP   C              37.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL             -290.6723
  J/KG              -1.5618+07
  KW                -6.6579+04
ENTROPY:
  CAL/MOL-K           -43.6936
  CAL/GM-K             -2.3477
DENSITY:
  MOL/CC              4.0564-02
  GM/CC                  0.7550
AVG MW                  18.6115

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
2
-

STREAM ID               2
FROM :                  B2
TO   :                  POLYHEAT

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                887.7925
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC            6163.4740
  DIETHER             9791.7798
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              1.6875+04
  KG/DAY              5.3848+04
  L/DAY               6.3084+04
STATE VARIABLES:
  TEMP   C              93.1981
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL             -261.9231
  J/KG              -1.9700+06
  KW                -1227.7808
ENTROPY:
  CAL/MOL-K          -259.2704
  CAL/GM-K             -1.9501
DENSITY:
  MOL/CC              6.4201-03
  GM/CC                  0.8536
AVG MW                 132.9556

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |

| | | | |
|---|---|---|---|
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

3
-

| | |
|---|---|
| STREAM ID | 3 |
| FROM : | XLAFERM |
| TO : | B12 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 3.0202+05 |
| GLUCOSE | 0.0 |
| XYLOSE | 488.7400 |
| AMMONIA | 0.0 |
| OTHLIQUI | 6.2002+04 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 1639.1820 |
| CELLULOS | 0.0 |
| ENZ/XYL | 3182.3591 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 3.6933+05 |
| KG/DAY | 1.7510+05 |
| L/DAY | 2.2213+05 |
| STATE VARIABLES: | |
| TEMP C | 32.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -296.4972 |
| J/KG | -1.5009+07 |
| KW | -3.0418+04 |
| ENTROPY: | |
| CAL/MOL-K | -41.2931 |
| CAL/GM-K | -2.0903 |
| DENSITY: | |
| MOL/CC | 3.9903-02 |
| GM/CC | 0.7883 |
| AVG MW | 19.7547 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

4
-

| | |
|---|---|
| STREAM ID | 4 |
| FROM : | EVAP2 |
| TO : | AAS |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 6.9387+05 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 4695.8931 |
| CELLULOS | 3539.4099 |
| ENZ/XYL | 0.1088 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 2.7190-09 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 7.0210+05 |
| KG/DAY | 3.1914+05 |
| L/DAY | 4.4233+05 |
| STATE VARIABLES: | |
| TEMP C | 110.0000 |
| PRES ATM | 1.2993 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -285.4353 |
| J/KG | -1.5071+07 |
| KW | -5.5668+04 |
| ENTROPY: | |
| CAL/MOL-K | -36.6408 |
| CAL/GM-K | -1.9346 |
| DENSITY: | |
| MOL/CC | 3.8095-02 |
| GM/CC | 0.7215 |
| AVG MW | 18.9397 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

5
-

```
STREAM ID              5
FROM :                 EVAP
TO   :                 B23

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER              2.6898+04
  GLUCOSE               0.0
  XYLOSE              488.6902
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL            3182.0769
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             3.0569+04
  KG/DAY             2.5010+04
  L/DAY              2.8025+04
STATE VARIABLES:
  TEMP   C            103.3036
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -370.3653
  J/KG              -1.0864+07
  KW                -3144.9305
ENTROPY:
  CAL/MOL-K           -55.2974
  CAL/GM-K             -1.6221
DENSITY:
  MOL/CC             2.6179-02
  GM/CC                 0.8924
  AVG MW               34.0897
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

7
-

```
STREAM ID              7
FROM :                 COOL2
TO   :                 FILTER2

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER              2.6898+04
  GLUCOSE               0.0
  XYLOSE              488.6902
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL            3182.0769
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             3.0569+04
  KG/DAY             2.5010+04
  L/DAY              2.6229+04
STATE VARIABLES:
  TEMP   C              5.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -380.9917
  J/KG              -1.1176+07
  KW                -3235.1634
ENTROPY:
```

```
  CAL/MOL-K             -63.1045
  CAL/GM-K               -1.8511
DENSITY:
  MOL/CC               2.7971-02
  GM/CC                   0.9535
AVG MW                   34.0897

STREAM COSTS
------------

ID                                  PRICE                            COST $/HR
-----------                         -----------------------------    ------------
AASWAT                               7.2647-04   $/L                      2.0027
BSG                                     0.0      $/KG                     0.0
CAOH                                    0.1760   $/KG                    54.1832
ENZYMES                                 0.5070   $/KG                   331.0499
LIQUOR                                  0.0      $/KG                     0.0
NACIT                                   1.9180   $/KG                   415.6513
NH3                                     0.3000   $/KG                   374.8750
PREC-PLA                                0.0      $/KG                     0.0
PREC-XYL                                0.0      $/KG                     0.0
PURE                                    0.0      $/KG                     0.0
SA-IN                                   0.2756   $/KG                    26.9951
STEAM3                                  0.0      $/KG                     0.0
STEAM4                                  0.0      $/KG                     0.0
XYLITOL                                 1.4330   $/KG                   589.7120

8
-

STREAM ID                 8
FROM :                    FILTER2
TO   :                    B23

SUBSTREAM: MIXED
PHASE:                    LIQUID
COMPONENTS: MOL/HR
  WATER                2.1519+04
  GLUCOSE                 0.0
  XYLOSE                488.7000
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL               477.3211
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR               2.2485+04
  KG/DAY               1.2808+04
  L/DAY                1.4946+04
STATE VARIABLES:
  TEMP   C                5.0000
  PRES   ATM              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
```

```
ENTHALPY:
  KJ/MOL               -322.1541
  J/KG                -1.3573+07
  KW                  -2012.1472
ENTROPY:
  CAL/MOL-K             -49.5701
  CAL/GM-K               -2.0886
DENSITY:
  MOL/CC               3.6106-02
  GM/CC                   0.8570
AVG MW                   23.7341

STREAM COSTS
------------

ID                                  PRICE                            COST $/HR
-----------                         -----------------------------    ------------
AASWAT                               7.2647-04   $/L                      2.0027
BSG                                     0.0      $/KG                     0.0
CAOH                                    0.1760   $/KG                    54.1832
ENZYMES                                 0.5070   $/KG                   331.0499
LIQUOR                                  0.0      $/KG                     0.0
NACIT                                   1.9180   $/KG                   415.6513
NH3                                     0.3000   $/KG                   374.8750
PREC-PLA                                0.0      $/KG                     0.0
PREC-XYL                                0.0      $/KG                     0.0
PURE                                    0.0      $/KG                     0.0
SA-IN                                   0.2756   $/KG                    26.9951
STEAM3                                  0.0      $/KG                     0.0
STEAM4                                  0.0      $/KG                     0.0
XYLITOL                                 1.4330   $/KG                   589.7120

9
-

STREAM ID                 9
FROM :                    FILTER2
TO   :                    WASH3

SUBSTREAM: MIXED
PHASE:                    LIQUID
COMPONENTS: MOL/HR
  WATER                5379.6749
  GLUCOSE                 0.0
  XYLOSE                  0.0
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL              2704.7653
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR               8084.4402
  KG/DAY               1.2203+04
  L/DAY                1.1175+04
STATE VARIABLES:
```

```
  TEMP   C              5.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -547.5449
  J/KG              -8.7062+06
  KW                -1229.6094
ENTROPY:
  CAL/MOL-K          -102.8881
  CAL/GM-K             -1.6360
DENSITY:
  MOL/CC             1.7362-02
  GM/CC                 1.0919
AVG MW                 62.8911

STREAM COSTS
------------

ID                                  PRICE                           COST $/HR
-----------                         -----------------------------   ------------
AASWAT                               7.2647-04   $/L                     2.0027
BSG                                     0.0      $/KG                    0.0
CAOH                                    0.1760   $/KG                   54.1832
ENZYMES                                 0.5070   $/KG                  331.0499
LIQUOR                                  0.0      $/KG                    0.0
NACIT                                   1.9180   $/KG                  415.6513
NH3                                     0.3000   $/KG                  374.8750
PREC-PLA                                0.0      $/KG                    0.0
PREC-XYL                                0.0      $/KG                    0.0
PURE                                    0.0      $/KG                    0.0
SA-IN                                   0.2756   $/KG                   26.9951
STEAM3                                  0.0      $/KG                    0.0
STEAM4                                  0.0      $/KG                    0.0
XYLITOL                                 1.4330   $/KG                  589.7120

11
--

STREAM ID               11
FROM :                  WASH3
TO   :                  CRYSTALL

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               5379.6749
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL             2704.7653
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
```

```
TOTAL FLOW:
  MOL/HR              8084.4402
  KG/DAY              1.2203+04
  L/DAY               1.1175+04
STATE VARIABLES:
  TEMP   C               5.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -547.5449
  J/KG               -8.7062+06
  KW                 -1229.6094
ENTROPY:
  CAL/MOL-K           -102.8881
  CAL/GM-K              -1.6360
DENSITY:
  MOL/CC              1.7362-02
  GM/CC                  1.0919
AVG MW                  62.8911

STREAM COSTS
------------

ID                                  PRICE                           COST $/HR
-----------                         -----------------------------   ------------
AASWAT                               7.2647-04   $/L                     2.0027
BSG                                     0.0      $/KG                    0.0
CAOH                                    0.1760   $/KG                   54.1832
ENZYMES                                 0.5070   $/KG                  331.0499
LIQUOR                                  0.0      $/KG                    0.0
NACIT                                   1.9180   $/KG                  415.6513
NH3                                     0.3000   $/KG                  374.8750
PREC-PLA                                0.0      $/KG                    0.0
PREC-XYL                                0.0      $/KG                    0.0
PURE                                    0.0      $/KG                    0.0
SA-IN                                   0.2756   $/KG                   26.9951
STEAM3                                  0.0      $/KG                    0.0
STEAM4                                  0.0      $/KG                    0.0
XYLITOL                                 1.4330   $/KG                  589.7120

AASPROD
-------

STREAM ID                AASPROD
FROM :                   AAS
TO   :                   WASH2

SUBSTREAM: MIXED
PHASE:                   MIXED
COMPONENTS: MOL/HR
  WATER               7.4381+05
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA             9983.5910
  OTHLIQUI            3.1840+04
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID            4695.8931
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
```

```
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR               7.9033+05
  KG/DAY               3.4913+05
  L/DAY                9.2381+06
STATE VARIABLES:
  TEMP   C               70.0000
  PRES   ATM              1.0000
  VFRAC                1.7092-02
  LFRAC                   0.9829
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -285.5104
  J/KG                -1.5511+07
  KW                  -6.2680+04
ENTROPY:
  CAL/MOL-K             -40.7199
  CAL/GM-K               -2.2123
DENSITY:
  MOL/CC               2.0532-03
  GM/CC                3.7793-02
AVG MW                   18.4065

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                             7.2647-04   $/L                       2.0027
BSG                                   0.0      $/KG                      0.0
CAOH                                  0.1760   $/KG                     54.1832
ENZYMES                               0.5070   $/KG                    331.0499
LIQUOR                                0.0      $/KG                      0.0
NACIT                                 1.9180   $/KG                    415.6513
NH3                                   0.3000   $/KG                    374.8750
PREC-PLA                              0.0      $/KG                      0.0
PREC-XYL                              0.0      $/KG                      0.0
PURE                                  0.0      $/KG                      0.0
SA-IN                                 0.2756   $/KG                     26.9951
STEAM3                                0.0      $/KG                      0.0
STEAM4                                0.0      $/KG                      0.0
XYLITOL                               1.4330   $/KG                    589.7120

AASWAT
------

STREAM ID               AASWAT
FROM :                  ----
TO   :                  WASH2

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                1.1564+05
  GLUCOSE                 0.0
  XYLOSE                  0.0
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL                 0.0
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
COST:
  $/HR                    2.0027
TOTAL FLOW:
  MOL/HR               1.1564+05
  KG/DAY               5.0000+04
  L/DAY                6.6162+04
STATE VARIABLES:
  TEMP   C               25.0000
  PRES   ATM              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -288.8616
  J/KG                -1.6034+07
  KW                  -9279.0822
ENTROPY:
  CAL/MOL-K             -40.8242
  CAL/GM-K               -2.2661
DENSITY:
  MOL/CC               4.1949-02
  GM/CC                   0.7557
AVG MW                   18.0153

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                             7.2647-04   $/L                       2.0027
BSG                                   0.0      $/KG                      0.0
CAOH                                  0.1760   $/KG                     54.1832
ENZYMES                               0.5070   $/KG                    331.0499
LIQUOR                                0.0      $/KG                      0.0
NACIT                                 1.9180   $/KG                    415.6513
NH3                                   0.3000   $/KG                    374.8750
PREC-PLA                              0.0      $/KG                      0.0
PREC-XYL                              0.0      $/KG                      0.0
PURE                                  0.0      $/KG                      0.0
SA-IN                                 0.2756   $/KG                     26.9951
STEAM3                                0.0      $/KG                      0.0
STEAM4                                0.0      $/KG                      0.0
XYLITOL                               1.4330   $/KG                    589.7120

BSG
---

STREAM ID               BSG
FROM :                  ----
TO   :                  WASH

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                2.2794+05
  GLUCOSE                 0.0
```

```
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS            1.4330+04
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
COST:
  $/HR                   0.0
TOTAL FLOW:
  MOL/HR              2.4227+05
  KG/DAY              1.6051+05
  L/DAY               1.7829+05
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -345.0984
  J/KG               -1.2501+07
  KW                 -2.3224+04
ENTROPY:
  CAL/MOL-K           -54.2020
  CAL/GM-K             -1.9634
DENSITY:
  MOL/CC              3.2612-02
  GM/CC                  0.9003
AVG MW                  27.6055
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

CAOH
----

```
STREAM ID               CAOH
FROM :                  ----
TO   :                  CAOH-NEU

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               1.4747+04
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                569.5119
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
COST:
  $/HR                  54.1832
TOTAL FLOW:
  MOL/HR              1.5316+04
  KG/DAY              7388.6200
  L/DAY               1.2918+04
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -299.4644
  J/KG               -1.4898+07
  KW                 -1274.0564
ENTROPY:
  CAL/MOL-K           -38.1571
  CAL/GM-K             -1.8983
DENSITY:
  MOL/CC              2.8455-02
  GM/CC                  0.5720
AVG MW                  20.1005
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |

| | | | |
|---|---|---|---|
| XYLITOL | 1.4330 | $/KG | 589.7120 |

CH2CL2IN
--------

| | |
|---|---|
| STREAM ID | CH2CL2IN |
| FROM : | ---- |
| TO : | CHLMIX |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 3.9247+04 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 3.9247+04 |
| KG/DAY | 8.0000+04 |
| L/DAY | 7.0102+04 |
| STATE VARIABLES: | |
| TEMP C | 25.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -124.3324 |
| J/KG | -1.4639+06 |
| KW | -1355.4630 |
| ENTROPY: | |
| CAL/MOL-K | -43.2094 |
| CAL/GM-K | -0.5088 |
| DENSITY: | |
| MOL/CC | 1.3436-02 |
| GM/CC | 1.1412 |
| AVG MW | 84.9323 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

ENZYMES
-------

| | |
|---|---|
| STREAM ID | ENZYMES |
| FROM : | ---- |
| TO : | SACCH |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 4291.6202 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| COST: | |
| $/HR | 331.0499 |
| TOTAL FLOW: | |
| MOL/HR | 4291.6202 |
| KG/DAY | 1.5671+04 |
| L/DAY | 1.2718+04 |
| STATE VARIABLES: | |
| TEMP C | 25.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -1062.5192 |
| J/KG | -6.9835+06 |
| KW | -1266.6469 |
| ENTROPY: | |
| CAL/MOL-K | -227.4091 |
| CAL/GM-K | -1.4947 |
| DENSITY: | |
| MOL/CC | 8.0988-03 |
| GM/CC | 1.2322 |
| AVG MW | 152.1473 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |

| | | | |
|---|---|---|---|
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

ETHIN
-----

| | |
|---|---|
| STREAM ID | ETHIN |
| FROM : | ---- |
| TO : | B14 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 9791.7798 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 9791.7798 |
| KG/DAY | 4.0000+04 |
| L/DAY | 4.8989+04 |
| STATE VARIABLES: | |
| TEMP C | 141.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | 18.4581 |
| J/KG | 1.0844+05 |
| KW | 50.2050 |
| ENTROPY: | |
| CAL/MOL-K | -108.6053 |
| CAL/GM-K | -0.6381 |
| DENSITY: | |
| MOL/CC | 4.7970-03 |
| GM/CC | 0.8165 |
| AVG MW | 170.2108 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

ETHIN2
------

| | |
|---|---|
| STREAM ID | ETHIN2 |
| FROM : | B14 |
| TO : | LLE |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 9791.7798 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 9791.7798 |
| KG/DAY | 4.0000+04 |
| L/DAY | 4.8989+04 |
| STATE VARIABLES: | |
| TEMP C | 141.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | 18.4581 |
| J/KG | 1.0844+05 |
| KW | 50.2050 |
| ENTROPY: | |
| CAL/MOL-K | -108.6053 |
| CAL/GM-K | -0.6381 |
| DENSITY: | |

```
  MOL/CC              4.7970-03
  GM/CC                  0.8165
AVG MW                 170.2108

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        ----------------------------    ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

ETHOUT1
-------

STREAM ID                ETHOUT1
FROM :                   ETHFLASH
TO   :                   B7

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: MOL/HR
  WATER                 610.0397
  GLUCOSE                32.1530
  XYLOSE                   0.0
  AMMONIA                  0.0
  OTHLIQUI                 0.0
  H2SO4                    0.0
  CAOH2                    0.0
  CASO4                    0.0
  OTHSOLID                 0.0
  CELLULOS                 0.0
  ENZ/XYL                  0.0
  NACIT                    0.0
  LACTICAC                 0.0
  DIETHER              9544.6563
  N2                       0.0
  METHANOL                 0.0
  CH2CL2                   0.0
  ETHYL-01                 0.0
  PLA                      0.0
TOTAL FLOW:
  MOL/HR              1.0187+04
  KG/DAY              3.9393+04
  L/DAY               4.9095+04
STATE VARIABLES:
  TEMP   C              157.4842
  PRES   ATM              1.0000
  VFRAC                    0.0
  LFRAC                   1.0000
  SFRAC                    0.0
ENTHALPY:
  KJ/MOL                  2.7036
  J/KG                1.6779+04
  KW                      7.6504
ENTROPY:
  CAL/MOL-K            -100.8350
  CAL/GM-K               -0.6258
DENSITY:
  MOL/CC              4.9799-03
  GM/CC                  0.8024
AVG MW                 161.1280

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        ----------------------------    ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

ETHOUT2
-------

STREAM ID                ETHOUT2
FROM :                   WATPUR
TO   :                   B7

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: MOL/HR
  WATER                  45.0061
  GLUCOSE              2.9138-06
  XYLOSE                   0.0
  AMMONIA                  0.0
  OTHLIQUI                 0.0
  H2SO4                    0.0
  CAOH2                    0.0
  CASO4                    0.0
  OTHSOLID                 0.0
  CELLULOS                 0.0
  ENZ/XYL                  0.0
  NACIT                    0.0
  LACTICAC                 0.0
  DIETHER               242.5761
  N2                       0.0
  METHANOL                 0.0
  CH2CL2                   0.0
  ETHYL-01                 0.0
  PLA                      0.0
TOTAL FLOW:
  MOL/HR                287.5822
  KG/DAY               1010.3970
  L/DAY                1215.1292
STATE VARIABLES:
  TEMP   C               90.0000
  PRES   ATM              1.0000
  VFRAC                    0.0
```

```
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL              -38.7207
  J/KG              -2.6450+05
  KW                  -3.0932
ENTROPY:
  CAL/MOL-K         -103.0995
  CAL/GM-K            -0.7043
DENSITY:
  MOL/CC            5.6800-03
  GM/CC                0.8315
AVG MW               146.3925

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                      2.0027
BSG                                    0.0      $/KG                     0.0
CAOH                                   0.1760   $/KG                    54.1832
ENZYMES                                0.5070   $/KG                   331.0499
LIQUOR                                 0.0      $/KG                     0.0
NACIT                                  1.9180   $/KG                   415.6513
NH3                                    0.3000   $/KG                   374.8750
PREC-PLA                               0.0      $/KG                     0.0
PREC-XYL                               0.0      $/KG                     0.0
PURE                                   0.0      $/KG                     0.0
SA-IN                                  0.2756   $/KG                    26.9951
STEAM3                                 0.0      $/KG                     0.0
STEAM4                                 0.0      $/KG                     0.0
XYLITOL                                1.4330   $/KG                   589.7120

ETHOUTFI
--------

STREAM ID               ETHOUTFI
FROM :                  B7
TO   :                  ----

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER                655.0458
  GLUCOSE               32.1530
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             9787.2324
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR            1.0474+04
  KG/DAY            4.0404+04
  L/DAY             5.8062+04
STATE VARIABLES:
  TEMP   C             155.7932
  PRES   ATM             1.0000
  VFRAC             8.8423-04
  LFRAC                 0.9991
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL                1.5663
  J/KG               9745.3099
  KW                    4.5572
ENTROPY:
  CAL/MOL-K         -100.8715
  CAL/GM-K            -0.6276
DENSITY:
  MOL/CC            4.3296-03
  GM/CC                0.6959
AVG MW               160.7234

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                      2.0027
BSG                                    0.0      $/KG                     0.0
CAOH                                   0.1760   $/KG                    54.1832
ENZYMES                                0.5070   $/KG                   331.0499
LIQUOR                                 0.0      $/KG                     0.0
NACIT                                  1.9180   $/KG                   415.6513
NH3                                    0.3000   $/KG                   374.8750
PREC-PLA                               0.0      $/KG                     0.0
PREC-XYL                               0.0      $/KG                     0.0
PURE                                   0.0      $/KG                     0.0
SA-IN                                  0.2756   $/KG                    26.9951
STEAM3                                 0.0      $/KG                     0.0
STEAM4                                 0.0      $/KG                     0.0
XYLITOL                                1.4330   $/KG                   589.7120

ETHPLA
------

STREAM ID               ETHPLA
FROM :                  PLAFLASH
TO   :                  B11

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: MOL/HR
  WATER               4736.6216
  GLUCOSE               32.1588
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             9778.5812
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
```

```
  ETHYL-01              0.0
  PLA                4.2709-21
TOTAL FLOW:
  MOL/HR             1.4547+04
  KG/DAY             4.2133+04
  L/DAY              1.5778+07
STATE VARIABLES:
  TEMP   C            288.0000
  PRES   ATM            1.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL                0.5687
  J/KG               4712.3768
  KW                    2.2980
ENTROPY:
  CAL/MOL-K           -42.6606
  CAL/GM-K             -0.3535
DENSITY:
  MOL/CC             2.2128-05
  GM/CC              2.6703-03
AVG MW                120.6779

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        ----------------------------    ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                    0.0      $/KG                   0.0
CAOH                                   0.1760   $/KG                  54.1832
ENZYMES                                0.5070   $/KG                 331.0499
LIQUOR                                 0.0      $/KG                   0.0
NACIT                                  1.9180   $/KG                 415.6513
NH3                                    0.3000   $/KG                 374.8750
PREC-PLA                               0.0      $/KG                   0.0
PREC-XYL                               0.0      $/KG                   0.0
PURE                                   0.0      $/KG                   0.0
SA-IN                                  0.2756   $/KG                  26.9951
STEAM3                                 0.0      $/KG                   0.0
STEAM4                                 0.0      $/KG                   0.0
XYLITOL                                1.4330   $/KG                 589.7120

HOHIN
-----

STREAM ID                HOHIN
FROM :                   ----
TO   :                   B10

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: MOL/HR
  WATER              4.6347+05
  GLUCOSE               0.0
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.0
  NACIT                 0.0
```

```
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             4.6347+05
  KG/DAY             2.0039+05
  L/DAY              2.6516+05
STATE VARIABLES:
  TEMP   C             25.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -288.8616
  J/KG              -1.6034+07
  KW                -3.7189+04
ENTROPY:
  CAL/MOL-K           -40.8242
  CAL/GM-K             -2.2661
DENSITY:
  MOL/CC             4.1949-02
  GM/CC                 0.7557
AVG MW                 18.0153

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        ----------------------------    ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                    0.0      $/KG                   0.0
CAOH                                   0.1760   $/KG                  54.1832
ENZYMES                                0.5070   $/KG                 331.0499
LIQUOR                                 0.0      $/KG                   0.0
NACIT                                  1.9180   $/KG                 415.6513
NH3                                    0.3000   $/KG                 374.8750
PREC-PLA                               0.0      $/KG                   0.0
PREC-XYL                               0.0      $/KG                   0.0
PURE                                   0.0      $/KG                   0.0
SA-IN                                  0.2756   $/KG                  26.9951
STEAM3                                 0.0      $/KG                   0.0
STEAM4                                 0.0      $/KG                   0.0
XYLITOL                                1.4330   $/KG                 589.7120

LIQUOR
------

STREAM ID                LIQUOR
FROM :                   CRYSTALL
TO   :                   ----

SUBSTREAM: MIXED
PHASE:                   LIQUID
COMPONENTS: MOL/HR
  WATER              5379.6749
  GLUCOSE               0.0
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
```

```
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.0
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
COST:
  $/HR                  0.0
TOTAL FLOW:
  MOL/HR             5379.6749
  KG/DAY             2325.9924
  L/DAY              3036.7727
STATE VARIABLES:
  TEMP   C              5.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -290.6010
  J/KG              -1.6131+07
  KW                 -434.2608
ENTROPY:
  CAL/MOL-K           -42.2666
  CAL/GM-K             -2.3462
DENSITY:
  MOL/CC             4.2516-02
  GM/CC                 0.7659
AVG MW                 18.0153

STREAM COSTS
------------

ID                                  PRICE                          COST $/HR
-----------                         -----------------------------  ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                    0.0      $/KG                   0.0
CAOH                                   0.1760   $/KG                  54.1832
ENZYMES                                0.5070   $/KG                 331.0499
LIQUOR                                 0.0      $/KG                   0.0
NACIT                                  1.9180   $/KG                 415.6513
NH3                                    0.3000   $/KG                 374.8750
PREC-PLA                               0.0      $/KG                   0.0
PREC-XYL                               0.0      $/KG                   0.0
PURE                                   0.0      $/KG                   0.0
SA-IN                                  0.2756   $/KG                  26.9951
STEAM3                                 0.0      $/KG                   0.0
STEAM4                                 0.0      $/KG                   0.0
XYLITOL                                1.4330   $/KG                 589.7120

MEOHIN
------

STREAM ID               MEOHIN
FROM :                  ----
TO   :                  B4

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
```

```
  WATER                 0.0
  GLUCOSE               0.0
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.0
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL           4.7018+04
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             4.7018+04
  KG/DAY             3.6158+04
  L/DAY              4.5600+04
STATE VARIABLES:
  TEMP   C             25.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -238.3998
  J/KG              -7.4402+06
  KW                -3113.6480
ENTROPY:
  CAL/MOL-K           -57.3816
  CAL/GM-K             -1.7908
DENSITY:
  MOL/CC             2.4746-02
  GM/CC                 0.7929
AVG MW                 32.0422

STREAM COSTS
------------

ID                                  PRICE                          COST $/HR
-----------                         -----------------------------  ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                    0.0      $/KG                   0.0
CAOH                                   0.1760   $/KG                  54.1832
ENZYMES                                0.5070   $/KG                 331.0499
LIQUOR                                 0.0      $/KG                   0.0
NACIT                                  1.9180   $/KG                 415.6513
NH3                                    0.3000   $/KG                 374.8750
PREC-PLA                               0.0      $/KG                   0.0
PREC-XYL                               0.0      $/KG                   0.0
PURE                                   0.0      $/KG                   0.0
SA-IN                                  0.2756   $/KG                  26.9951
STEAM3                                 0.0      $/KG                   0.0
STEAM4                                 0.0      $/KG                   0.0
XYLITOL                                1.4330   $/KG                 589.7120

NACIT
-----

STREAM ID               NACIT
FROM :                  ----
```

```
TO   :                  SACCH

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                  0.0
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT               3708.0625
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
COST:
  $/HR                 415.6513
TOTAL FLOW:
  MOL/HR              3708.0625
  KG/DAY              5201.0000
  L/DAY               6233.4334
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -445.7720
  J/KG               -7.6275+06
  KW                  -459.1529
ENTROPY:
  CAL/MOL-K            -31.0800
  CAL/GM-K              -0.5318
DENSITY:
  MOL/CC              1.4277-02
  GM/CC                  0.8344
AVG MW                  58.4425

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
NH3
---

STREAM ID               NH3
FROM :                  ----
TO   :                  AAS

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               4.9941+04
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA             9983.5910
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
COST:
  $/HR                 374.8750
TOTAL FLOW:
  MOL/HR              5.9925+04
  KG/DAY              2.9990+04
  L/DAY               5.5321+06
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   ATM             1.0000
  VFRAC                  0.1705
  LFRAC                  0.8295
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -301.7511
  J/KG               -1.4471+07
  KW                 -5022.8586
ENTROPY:
  CAL/MOL-K            -82.8665
  CAL/GM-K              -3.9739
DENSITY:
  MOL/CC              2.5997-04
  GM/CC               5.4211-03
AVG MW                  20.8526

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |

| | | | |
|---|---|---|---|
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

PLA
---

| | |
|---|---|
| STREAM ID | PLA |
| FROM : | PLAFLASH |
| TO : | CHLMIX |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 4.4330-02 |
| GLUCOSE | 1.8696-02 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 2.6769 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 5.6034 |
| TOTAL FLOW: | |
| MOL/HR | 8.3433 |
| KG/DAY | 1.0671+04 |
| L/DAY | 658.4520 |
| STATE VARIABLES: | |
| TEMP C | 288.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -365.5821 |
| J/KG | -6859.8799 |
| KW | -0.8473 |
| ENTROPY: | |
| CAL/MOL-K | -204.9916 |
| CAL/GM-K | -3.8465-03 |
| DENSITY: | |
| MOL/CC | 3.0411-04 |
| GM/CC | 16.2066 |
| AVG MW | 5.3293+04 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

PLA1
----

| | |
|---|---|
| STREAM ID | PLA1 |
| FROM : | POLYREAC |
| TO : | B19 |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 9474.2927 |
| GLUCOSE | 64.3546 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 1.9565+04 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 11.2064 |
| TOTAL FLOW: | |
| MOL/HR | 2.9115+04 |
| KG/DAY | 1.0562+05 |
| L/DAY | 8.1744+06 |
| STATE VARIABLES: | |
| TEMP C | 170.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.3202 |
| LFRAC | 0.6798 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -60.5489 |
| J/KG | -4.0058+05 |
| KW | -489.6922 |
| ENTROPY: | |
| CAL/MOL-K | -71.9658 |
| CAL/GM-K | -0.4761 |
| DENSITY: | |
| MOL/CC | 8.5482-05 |
| GM/CC | 1.2921-02 |
| AVG MW | 151.1527 |

STREAM COSTS

------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

PLAOUT
------

| | |
|---|---|
| STREAM ID | PLAOUT |
| FROM : | B4 |
| TO : | ---- |
| SUBSTREAM: MIXED | |
| PHASE: | MISSING |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 5.6034 |
| TOTAL FLOW: | |
| MOL/HR | 5.6034 |
| KG/DAY | 1.0660+04 |
| L/DAY | 1.0660+07 |
| STATE VARIABLES: | |
| TEMP C | 25.8549 |
| PRES ATM | 1.0000 |
| AVG MW | 7.9270+04 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

PLAREC
------

| | |
|---|---|
| STREAM ID | PLAREC |
| FROM : | DRYPLA |
| TO : | POLYREAC |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 2423.0262 |
| GLUCOSE | 32.1773 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 9773.5421 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 5.6032 |
| TOTAL FLOW: | |
| MOL/HR | 1.2234+04 |
| KG/DAY | 5.1772+04 |
| L/DAY | 5.0623+04 |
| STATE VARIABLES: | |
| TEMP C | 99.8609 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -50.9332 |
| J/KG | -2.8887+05 |
| KW | -173.0928 |
| ENTROPY: | |
| CAL/MOL-K | -98.0774 |
| CAL/GM-K | -0.5562 |
| DENSITY: | |
| MOL/CC | 5.8003-03 |
| GM/CC | 1.0227 |
| AVG MW | 176.3216 |

STREAM COSTS
------------

ID PRICE COST $/HR

| | | | |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

PLASUGAR
--------

| | |
|---|---|
| STREAM ID | PLASUGAR |
| FROM : | FUGEPLA |
| TO : | B15 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 8.1648+05 |
| GLUCOSE | 3539.5017 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 8.2002+05 |
| KG/DAY | 3.6832+05 |
| L/DAY | 4.7736+05 |
| STATE VARIABLES: | |
| TEMP C | 25.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -293.1794 |
| J/KG | -1.5665+07 |
| KW | -6.6781+04 |
| ENTROPY: | |
| CAL/MOL-K | -41.8127 |
| CAL/GM-K | -2.2342 |
| DENSITY: | |
| MOL/CC | 4.1228-02 |
| GM/CC | 0.7716 |
| AVG MW | 18.7151 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

PREC-PLA
--------

| | |
|---|---|
| STREAM ID | PREC-PLA |
| FROM : | FUGEPLA |
| TO : | ---- |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 4.2973+04 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 9983.5910 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 4695.8931 |
| CELLULOS | 0.0 |
| ENZ/XYL | 4291.6202 |
| NACIT | 3708.0625 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| COST: | |
| $/HR | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 6.5652+04 |
| KG/DAY | 5.1683+04 |
| L/DAY | 5.5182+06 |
| STATE VARIABLES: | |
| TEMP C | 25.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.1548 |
| LFRAC | 0.8452 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -350.6459 |
| J/KG | -1.0690+07 |
| KW | -6394.5912 |

```
ENTROPY:
  CAL/MOL-K            -90.8295
  CAL/GM-K              -2.7691
DENSITY:
  MOL/CC              2.8553-04
  GM/CC               9.3658-03
AVG MW                  32.8010

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
PREC-XYL
--------

STREAM ID               PREC-XYL
FROM :                  FUGEXYL
TO   :                  ----

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               5944.0484
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                 32.9029
  CAOH2                 28.4756
  CASO4                541.0364
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
COST:
  $/HR                   0.0
TOTAL FLOW:
  MOL/HR              6546.4633
  KG/DAY              4465.8765
  L/DAY               7901.4840
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -388.8234
  J/KG              -1.3679+07
  KW                  -707.0605
ENTROPY:
  CAL/MOL-K           -130.1125
  CAL/GM-K              -4.5775
DENSITY:
  MOL/CC              1.9884-02
  GM/CC                  0.5652
AVG MW                  28.4242

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
PROD-C
------

STREAM ID               PROD-C
FROM :                  B20
TO   :                  FILTER

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               1.0532+06
  GLUCOSE                4.2792
  XYLOSE              3593.8629
  AMMONIA                0.0
  OTHLIQUI            6.2002+04
  H2SO4                573.9393
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID            4781.4643
  CELLULOS            3539.4104
  ENZ/XYL                0.1088
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.7259-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              1.1277+06
```

```
  KG/DAY              5.1868+05
  L/DAY               1.8739+07
STATE VARIABLES:
  TEMP   C             102.7762
  PRES   ATM             1.0000
  VFRAC               2.1796-02
  LFRAC                  0.9782
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -286.5859
  J/KG               -1.4954+07
  KW                 -8.9770+04
ENTROPY:
  CAL/MOL-K            -36.2300
  CAL/GM-K              -1.8904
DENSITY:
  MOL/CC              1.4442-03
  GM/CC               2.7679-02
AVG MW                  19.1651

STREAM COSTS
------------

ID                                  PRICE                            COST $/HR
-----------                         -----------------------------    ------------
AASWAT                               7.2647-04   $/L                      2.0027
BSG                                     0.0      $/KG                     0.0
CAOH                                    0.1760   $/KG                    54.1832
ENZYMES                                 0.5070   $/KG                   331.0499
LIQUOR                                  0.0      $/KG                     0.0
NACIT                                   1.9180   $/KG                   415.6513
NH3                                     0.3000   $/KG                   374.8750
PREC-PLA                                0.0      $/KG                     0.0
PREC-XYL                                0.0      $/KG                     0.0
PURE                                    0.0      $/KG                     0.0
SA-IN                                   0.2756   $/KG                    26.9951
STEAM3                                  0.0      $/KG                     0.0
STEAM4                                  0.0      $/KG                     0.0
XYLITOL                                 1.4330   $/KG                   589.7120

PROD-H
------

STREAM ID               PROD-H
FROM :                  SA-HYDRO
TO   :                  B20

CONV. MAX. REL. ERR: -3.3165-07
SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               1.0532+06
  GLUCOSE                4.2792
  XYLOSE              3593.8629
  AMMONIA                0.0
  OTHLIQUI            6.2002+04
  H2SO4                573.9393
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID            4781.4643
  CELLULOS            3539.4104
  ENZ/XYL                0.1088
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.7259-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              1.1277+06
  KG/DAY              5.1868+05
  L/DAY               9.2638+08
STATE VARIABLES:
  TEMP   C             150.0000
  PRES   ATM             1.0000
  VFRAC                  0.9917
  LFRAC               8.3049-03
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -243.3661
  J/KG               -1.2698+07
  KW                 -7.6232+04
ENTROPY:
  CAL/MOL-K             -8.8748
  CAL/GM-K              -0.4631
DENSITY:
  MOL/CC              2.9215-05
  GM/CC               5.5990-04
AVG MW                  19.1651

STREAM COSTS
------------

ID                                  PRICE                            COST $/HR
-----------                         -----------------------------    ------------
AASWAT                               7.2647-04   $/L                      2.0027
BSG                                     0.0      $/KG                     0.0
CAOH                                    0.1760   $/KG                    54.1832
ENZYMES                                 0.5070   $/KG                   331.0499
LIQUOR                                  0.0      $/KG                     0.0
NACIT                                   1.9180   $/KG                   415.6513
NH3                                     0.3000   $/KG                   374.8750
PREC-PLA                                0.0      $/KG                     0.0
PREC-XYL                                0.0      $/KG                     0.0
PURE                                    0.0      $/KG                     0.0
SA-IN                                   0.2756   $/KG                    26.9951
STEAM3                                  0.0      $/KG                     0.0
STEAM4                                  0.0      $/KG                     0.0
XYLITOL                                 1.4330   $/KG                   589.7120

PURE
----

STREAM ID               PURE
FROM :                  B25
TO   :                  B2

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                887.7925
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
```

```
  CELLULOS              0.0
  ENZ/XYL               0.0
  NACIT                 0.0
  LACTICAC           6163.4740
  DIETHER            9791.7798
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
COST:
  $/HR                  0.0
TOTAL FLOW:
  MOL/HR             1.6875+04
  KG/DAY             5.3848+04
  L/DAY              6.0688+04
STATE VARIABLES:
  TEMP   C             22.0031
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -278.3628
  J/KG              -2.0937+06
  KW                -1304.8427
ENTROPY:
  CAL/MOL-K          -271.1606
  CAL/GM-K             -2.0395
DENSITY:
  MOL/CC             6.6736-03
  GM/CC                 0.8873
AVG MW                132.9556

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------    ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

PURGE
-----

STREAM ID               PURGE
FROM :                  SPLIT
TO   :                  ----

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER              1.0760+04
  GLUCOSE               0.0
  XYLOSE              244.3500
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL             238.6606
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             1.1243+04
  KG/DAY             6404.0166
  L/DAY              7988.6620
STATE VARIABLES:
  TEMP   C             95.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -313.6615
  J/KG              -1.3216+07
  KW                 -979.5516
ENTROPY:
  CAL/MOL-K           -43.2539
  CAL/GM-K             -1.8224
DENSITY:
  MOL/CC             3.3776-02
  GM/CC                 0.8016
AVG MW                 23.7341

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------    ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

RECYCLE
-------

STREAM ID               RECYCLE
FROM :                  SPLIT
TO   :                  B22
```

```
SUBSTREAM: MIXED
PHASE:                    LIQUID
COMPONENTS: MOL/HR
  WATER                 1.0760+04
  GLUCOSE                  0.0
  XYLOSE                 244.3500
  AMMONIA                  0.0
  OTHLIQUI                 0.0
  H2SO4                    0.0
  CAOH2                    0.0
  CASO4                    0.0
  OTHSOLID                 0.0
  CELLULOS                 0.0
  ENZ/XYL                238.6606
  NACIT                    0.0
  LACTICAC                 0.0
  DIETHER                  0.0
  N2                       0.0
  METHANOL                 0.0
  CH2CL2                   0.0
  ETHYL-01                 0.0
  PLA                      0.0
TOTAL FLOW:
  MOL/HR                1.1243+04
  KG/DAY                6404.0166
  L/DAY                 7988.6620
STATE VARIABLES:
  TEMP   C                95.0000
  PRES   ATM               1.0000
  VFRAC                    0.0
  LFRAC                    1.0000
  SFRAC                    0.0
ENTHALPY:
  KJ/MOL                -313.6615
  J/KG                 -1.3216+07
  KW                    -979.5516
ENTROPY:
  CAL/MOL-K              -43.2539
  CAL/GM-K                -1.8224
DENSITY:
  MOL/CC                3.3776-02
  GM/CC                    0.8016
AVG MW                    23.7341

STREAM COSTS
------------

ID                                   PRICE                            COST $/HR
-----------                          -----------------------------    ------------
AASWAT                                7.2647-04   $/L                      2.0027
BSG                                      0.0      $/KG                     0.0
CAOH                                     0.1760   $/KG                    54.1832
ENZYMES                                  0.5070   $/KG                   331.0499
LIQUOR                                   0.0      $/KG                     0.0
NACIT                                    1.9180   $/KG                   415.6513
NH3                                      0.3000   $/KG                   374.8750
PREC-PLA                                 0.0      $/KG                     0.0
PREC-XYL                                 0.0      $/KG                     0.0
PURE                                     0.0      $/KG                     0.0
SA-IN                                    0.2756   $/KG                    26.9951
STEAM3                                   0.0      $/KG                     0.0
STEAM4                                   0.0      $/KG                     0.0
XYLITOL                                  1.4330   $/KG                   589.7120

S1
--
```

```
STREAM ID                S1
FROM :                   B3
TO   :                   B2

SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: MOL/HR
  WATER                6440.5528
  GLUCOSE              5.8179-03
  XYLOSE                  0.0
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL                 0.0
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER               242.5760
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                  9.5277-24
TOTAL FLOW:
  MOL/HR               6683.1346
  KG/DAY               3775.6430
  L/DAY                5.4081+06
STATE VARIABLES:
  TEMP   C              140.8396
  PRES   ATM              1.0000
  VFRAC                   1.0000
  LFRAC                   0.0
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -226.5644
  J/KG                -9.6248+06
  KW                   -420.6000
ENTROPY:
  CAL/MOL-K             -10.3718
  CAL/GM-K               -0.4406
DENSITY:
  MOL/CC               2.9658-05
  GM/CC                6.9815-04
AVG MW                   23.5396

STREAM COSTS
------------

ID                                   PRICE                            COST $/HR
-----------                          -----------------------------    ------------
AASWAT                                7.2647-04   $/L                      2.0027
BSG                                      0.0      $/KG                     0.0
CAOH                                     0.1760   $/KG                    54.1832
ENZYMES                                  0.5070   $/KG                   331.0499
LIQUOR                                   0.0      $/KG                     0.0
NACIT                                    1.9180   $/KG                   415.6513
NH3                                      0.3000   $/KG                   374.8750
PREC-PLA                                 0.0      $/KG                     0.0
PREC-XYL                                 0.0      $/KG                     0.0
PURE                                     0.0      $/KG                     0.0
SA-IN                                    0.2756   $/KG                    26.9951
STEAM3                                   0.0      $/KG                     0.0
```

| | | | |
|---|---|---|---|
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S2
--

```
STREAM ID               S2
FROM :                  B5
TO   :                  WASH

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               8.2291+05
  GLUCOSE             5.8149-03
  XYLOSE              2.3098-02
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS            5.5705-04
  ENZ/XYL                0.1081
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.5375-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              8.2292+05
  KG/DAY              3.5580+05
  L/DAY               4.9848+05
STATE VARIABLES:
  TEMP   C              95.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -282.7809
  J/KG               -1.5697+07
  KW                 -6.4640+04
ENTROPY:
  CAL/MOL-K            -36.4492
  CAL/GM-K              -2.0232
DENSITY:
  MOL/CC              3.9621-02
  GM/CC                  0.7138
AVG MW                  18.0153
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S3
--

```
STREAM ID               S3
FROM :                  POLYHEAT
TO   :                  POLYREAC

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                887.7925
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC            6163.4740
  DIETHER             9791.7798
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              1.6875+04
  KG/DAY              5.3848+04
  L/DAY               6.6764+04
STATE VARIABLES:
  TEMP   C             170.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -241.7789
  J/KG               -1.8185+06
  KW                 -1133.3538
ENTROPY:
  CAL/MOL-K           -247.3708
  CAL/GM-K              -1.8606
DENSITY:
  MOL/CC              6.0662-03
  GM/CC                  0.8065
AVG MW                 132.9556
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |

| | | | |
|---|---|---|---|
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S4
--

STREAM ID S4
FROM : B19
TO : PSPLIT

CONV. MAX. REL. ERR: -1.0331-07
SUBSTREAM: MIXED

| | |
|---|---|
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 9474.2927 |
| GLUCOSE | 64.3546 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 1.9565+04 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 11.2064 |
| TOTAL FLOW: | |
| MOL/HR | 2.9115+04 |
| KG/DAY | 1.0562+05 |
| L/DAY | 4.5424+06 |
| STATE VARIABLES: | |
| TEMP C | 110.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.2038 |
| LFRAC | 0.7962 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -77.4753 |
| J/KG | -5.1256+05 |
| KW | -626.5854 |
| ENTROPY: | |
| CAL/MOL-K | -81.7674 |
| CAL/GM-K | -0.5410 |
| DENSITY: | |
| MOL/CC | 1.5383-04 |
| GM/CC | 2.3252-02 |
| AVG MW | 151.1527 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S5
--

STREAM ID S5
FROM : FILTER
TO : EVAP2

SUBSTREAM: MIXED

| | |
|---|---|
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 7.7179+05 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 4781.4643 |
| CELLULOS | 3539.4104 |
| ENZ/XYL | 0.1088 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 4.7259-05 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 7.8012+05 |
| KG/DAY | 3.5291+05 |
| L/DAY | 1.4961+08 |
| STATE VARIABLES: | |
| TEMP C | 102.7762 |
| PRES ATM | 1.0000 |
| VFRAC | 0.2606 |
| LFRAC | 0.7394 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -274.5095 |
| J/KG | -1.4564+07 |
| KW | -5.9486+04 |
| ENTROPY: | |
| CAL/MOL-K | -29.8486 |
| CAL/GM-K | -1.5836 |

```
DENSITY:
  MOL/CC              1.2514-04
  GM/CC               2.3588-03
AVG MW                  18.8490

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                 0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                 0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                 0.0
PREC-XYL                               0.0      $/KG                 0.0
PURE                                   0.0      $/KG                 0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                 0.0
STEAM4                                 0.0      $/KG                 0.0
XYLITOL                                1.4330   $/KG                  589.7120

S6
--

STREAM ID              S6
FROM :                 B6
TO   :                 B5

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: MOL/HR
  WATER               3.5305+05
  GLUCOSE                0.0
  XYLOSE              2.3098-02
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID              85.5712
  CELLULOS            5.5705-04
  ENZ/XYL                0.1081
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.7257-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              3.5313+05
  KG/DAY              1.5272+05
  L/DAY               2.8909+08
STATE VARIABLES:
  TEMP   C             145.1174
  PRES   ATM             1.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -237.7758
  J/KG               -1.3196+07
  KW                 -2.3324+04
ENTROPY:
  CAL/MOL-K             -7.8899
  CAL/GM-K              -0.4379
DENSITY:
  MOL/CC              2.9316-05
  GM/CC               5.2826-04
AVG MW                  18.0192

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                 0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                 0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                 0.0
PREC-XYL                               0.0      $/KG                 0.0
PURE                                   0.0      $/KG                 0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                 0.0
STEAM4                                 0.0      $/KG                 0.0
XYLITOL                                1.4330   $/KG                  589.7120

S7
--

STREAM ID              S7
FROM :                 CHLMIX
TO   :                 B4

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER               4.4330-02
  GLUCOSE             1.8696-02
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                2.6769
  N2                     0.0
  METHANOL               0.0
  CH2CL2              3.9247+04
  ETHYL-01               0.0
  PLA                    5.6034
TOTAL FLOW:
  MOL/HR              3.9255+04
  KG/DAY              9.0671+04
  L/DAY               7.0816+04
STATE VARIABLES:
  TEMP   C              24.1064
  PRES   ATM             1.0000
```

```
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -124.3836
  J/KG               -1.2924+06
  KW                 -1356.3103
ENTROPY:
  CAL/MOL-K            -43.2611
  CAL/GM-K              -0.4495
DENSITY:
  MOL/CC              1.3304-02
  GM/CC                 1.2804
AVG MW                 96.2410

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                     0.0     $/KG                   0.0
CAOH                                    0.1760  $/KG                  54.1832
ENZYMES                                 0.5070  $/KG                 331.0499
LIQUOR                                  0.0     $/KG                   0.0
NACIT                                   1.9180  $/KG                 415.6513
NH3                                     0.3000  $/KG                 374.8750
PREC-PLA                                0.0     $/KG                   0.0
PREC-XYL                                0.0     $/KG                   0.0
PURE                                    0.0     $/KG                   0.0
SA-IN                                   0.2756  $/KG                  26.9951
STEAM3                                  0.0     $/KG                   0.0
STEAM4                                  0.0     $/KG                   0.0
XYLITOL                                 1.4330  $/KG                 589.7120

S8
--

STREAM ID              S8
FROM :                 B4
TO   :                 B18

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER               4.4330-02
  GLUCOSE             1.8696-02
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.0
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               2.6769
  N2                    0.0
  METHANOL            4.7018+04
  CH2CL2              3.9247+04
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR              8.6268+04
```

```
  KG/DAY              1.1617+05
  L/DAY               1.0504+05
STATE VARIABLES:
  TEMP   C              25.8549
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL             -186.5084
  J/KG               -3.3241+06
  KW                 -4469.3582
ENTROPY:
  CAL/MOL-K            -49.6021
  CAL/GM-K              -0.8840
DENSITY:
  MOL/CC              1.9710-02
  GM/CC                 1.1059
AVG MW                 56.1084

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                     0.0     $/KG                   0.0
CAOH                                    0.1760  $/KG                  54.1832
ENZYMES                                 0.5070  $/KG                 331.0499
LIQUOR                                  0.0     $/KG                   0.0
NACIT                                   1.9180  $/KG                 415.6513
NH3                                     0.3000  $/KG                 374.8750
PREC-PLA                                0.0     $/KG                   0.0
PREC-XYL                                0.0     $/KG                   0.0
PURE                                    0.0     $/KG                   0.0
SA-IN                                   0.2756  $/KG                  26.9951
STEAM3                                  0.0     $/KG                   0.0
STEAM4                                  0.0     $/KG                   0.0
XYLITOL                                 1.4330  $/KG                 589.7120

S9
--

STREAM ID              S9
FROM :                 PSPLIT
TO   :                 DRYPLA

SUBSTREAM: MIXED
PHASE:                 MIXED
COMPONENTS: MOL/HR
  WATER               4736.9972
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             9782.1932
  N2                     0.0
  METHANOL               0.0
```

```
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   5.6032
TOTAL FLOW:
  MOL/HR             1.4557+04
  KG/DAY             5.2808+04
  L/DAY              2.2712+06
STATE VARIABLES:
  TEMP   C           110.0002
  PRES   ATM           1.0000
  VFRAC                0.2038
  LFRAC                0.7962
  SFRAC                0.0
ENTHALPY:
  KJ/MOL             -77.4762
  J/KG              -5.1257+05
  KW                -313.2832
ENTROPY:
  CAL/MOL-K          -81.7670
  CAL/GM-K            -0.5410
DENSITY:
  MOL/CC             1.5383-04
  GM/CC              2.3252-02
AVG MW               151.1537

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

S10
---

STREAM ID               S10
FROM :                  B5
TO   :                  B8

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER              3.5305+05
  GLUCOSE               0.0
  XYLOSE             2.3098-02
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID             85.5712
  CELLULOS           5.5705-04
  ENZ/XYL               0.1081
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER            4.7257-05
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             3.5313+05
  KG/DAY             1.5272+05
  L/DAY              2.2363+08
STATE VARIABLES:
  TEMP   C           102.4610
  PRES   ATM           1.0000
  VFRAC                0.8632
  LFRAC                0.1368
  SFRAC                0.0
ENTHALPY:
  KJ/MOL            -245.1113
  J/KG              -1.3603+07
  KW                -2.4043+04
ENTROPY:
  CAL/MOL-K          -12.5048
  CAL/GM-K            -0.6940
DENSITY:
  MOL/CC             3.7898-05
  GM/CC              6.8290-04
AVG MW                18.0192

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

S11
---

STREAM ID               S11
FROM :                  B8
TO   :                  SA-HYDRO

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER              2312.8515
  GLUCOSE               0.0
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4               573.9393
```

```
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              2886.7907
  KG/DAY              2351.0000
  L/DAY               2974.8273
STATE VARIABLES:
  TEMP   C              92.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -393.7318
  J/KG               -1.1603+07
  KW                  -315.7282
ENTROPY:
  CAL/MOL-K            -49.1532
  CAL/GM-K              -1.4485
DENSITY:
  MOL/CC              2.3290-02
  GM/CC                  0.7903
AVG MW                  33.9333
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S12
---

```
STREAM ID               S12
FROM :                  PSPLIT
TO   :                  B11

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               4736.9972
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             9782.1932
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    5.6032
TOTAL FLOW:
  MOL/HR              1.4557+04
  KG/DAY              5.2808+04
  L/DAY               2.2712+06
STATE VARIABLES:
  TEMP   C             110.0002
  PRES   ATM             1.0000
  VFRAC                  0.2038
  LFRAC                  0.7962
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL               -77.4762
  J/KG               -5.1257+05
  KW                  -313.2832
ENTROPY:
  CAL/MOL-K            -81.7670
  CAL/GM-K              -0.5410
DENSITY:
  MOL/CC              1.5383-04
  GM/CC               2.3252-02
AVG MW                 151.1537
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S13
---

```
STREAM ID               S13
FROM :                  B11
TO   :                  B17
```

SUBSTREAM: MIXED

| | |
|---|---|
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 4736.9972 |
| GLUCOSE | 32.1773 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 9782.1932 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 5.6032 |
| TOTAL FLOW: | |
| MOL/HR | 1.4557+04 |
| KG/DAY | 5.2808+04 |
| L/DAY | 1.1769+07 |
| STATE VARIABLES: | |
| TEMP C | 237.4785 |
| PRES ATM | 1.0000 |
| VFRAC | 0.8207 |
| LFRAC | 0.1793 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -19.6443 |
| J/KG | -1.2996+05 |
| KW | -79.4337 |
| ENTROPY: | |
| CAL/MOL-K | -51.8530 |
| CAL/GM-K | -0.3430 |
| DENSITY: | |
| MOL/CC | 2.9684-05 |
| GM/CC | 4.4869-03 |
| AVG MW | 151.1537 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S14

---

| | |
|---|---|
| STREAM ID | S14 |
| FROM : | B11 |
| TO : | ETHFLASH |

SUBSTREAM: MIXED

| | |
|---|---|
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 4736.6216 |
| GLUCOSE | 32.1588 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 9778.5812 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 4.2709-21 |
| TOTAL FLOW: | |
| MOL/HR | 1.4547+04 |
| KG/DAY | 4.2133+04 |
| L/DAY | 4.4220+06 |
| STATE VARIABLES: | |
| TEMP C | 180.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.3396 |
| LFRAC | 0.6604 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -57.3015 |
| J/KG | -4.7483+05 |
| KW | -231.5515 |
| ENTROPY: | |
| CAL/MOL-K | -70.2409 |
| CAL/GM-K | -0.5821 |
| DENSITY: | |
| MOL/CC | 7.8954-05 |
| GM/CC | 9.5280-03 |
| AVG MW | 120.6779 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |

```
STEAM3                                 0.0      $/KG                  0.0
STEAM4                                 0.0      $/KG                  0.0
XYLITOL                                1.4330   $/KG                589.7120

S15
---

STREAM ID               S15
FROM :                  B8
TO   :                  B13


CONV. MAX. REL. ERR: -7.7978-11
SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               3.5305+05
  GLUCOSE                0.0
  XYLOSE              2.3098-02
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID              85.5712
  CELLULOS            5.5705-04
  ENZ/XYL                0.1081
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.7257-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              3.5313+05
  KG/DAY              1.5272+05
  L/DAY               2.2326+08
STATE VARIABLES:
  TEMP   C             102.4609
  PRES   ATM             1.0000
  VFRAC                  0.8618
  LFRAC                  0.1382
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -245.1722
  J/KG               -1.3606+07
  KW                 -2.4049+04
ENTROPY:
  CAL/MOL-K            -12.5436
  CAL/GM-K              -0.6961
DENSITY:
  MOL/CC              3.7961-05
  GM/CC               6.8403-04
AVG MW                  18.0192

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                   2.0027
BSG                                    0.0      $/KG                  0.0
CAOH                                   0.1760   $/KG                 54.1832
ENZYMES                                0.5070   $/KG                331.0499
```

```
LIQUOR                                 0.0      $/KG                  0.0
NACIT                                  1.9180   $/KG                415.6513
NH3                                    0.3000   $/KG                374.8750
PREC-PLA                               0.0      $/KG                  0.0
PREC-XYL                               0.0      $/KG                  0.0
PURE                                   0.0      $/KG                  0.0
SA-IN                                  0.2756   $/KG                 26.9951
STEAM3                                 0.0      $/KG                  0.0
STEAM4                                 0.0      $/KG                  0.0
XYLITOL                                1.4330   $/KG                589.7120

S16
---

STREAM ID               S16
FROM :                  B9
TO   :                  LLE

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               8.1648+05
  GLUCOSE               32.1773
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC            6371.1031
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              8.2288+05
  KG/DAY              3.6693+05
  L/DAY               4.8678+05
STATE VARIABLES:
  TEMP   C              37.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -290.8789
  J/KG               -1.5656+07
  KW                 -6.6489+04
ENTROPY:
  CAL/MOL-K            -43.6981
  CAL/GM-K              -2.3519
DENSITY:
  MOL/CC              4.0571-02
  GM/CC                  0.7538
AVG MW                  18.5796

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
```

| | | | |
|---|---|---|---|
| ----------- | ----------------------------- | | ------------ |
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S17
---

| | |
|---|---|
| STREAM ID | S17 |
| FROM : | B9 |
| TO : | ---- |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 1704.2599 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 1704.2599 |
| KG/DAY | 1391.2766 |
| L/DAY | 1100.1266 |
| STATE VARIABLES: | |
| TEMP C | 37.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -190.8871 |
| J/KG | -5.6119+06 |
| KW | -90.3670 |
| ENTROPY: | |
| CAL/MOL-K | -55.7109 |
| CAL/GM-K | -1.6378 |
| DENSITY: | |
| MOL/CC | 3.7180-02 |
| GM/CC | 1.2647 |
| AVG MW | 34.0147 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| ----------- | ----------------------------- | | ------------ |
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S18
---

| | |
|---|---|
| STREAM ID | S18 |
| FROM : | CHROMA |
| TO : | ---- |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 6.2002+04 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 6.2002+04 |
| KG/DAY | 2.9802+04 |
| L/DAY | 3.6081+04 |
| STATE VARIABLES: | |
| TEMP C | 32.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -296.3694 |
| J/KG | -1.4798+07 |
| KW | -5104.3229 |
| ENTROPY: | |
| CAL/MOL-K | -41.8349 |

```
  CAL/GM-K              -2.0889
DENSITY:
  MOL/CC              4.1242-02
  GM/CC                  0.8260
AVG MW                  20.0274

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

S19
---

STREAM ID               S19
FROM :                  B10
TO   :                  B21

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               8.2291+05
  GLUCOSE             5.8149-03
  XYLOSE              2.3098-02
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID              85.5711
  CELLULOS            5.5705-04
  ENZ/XYL                0.1081
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.5375-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              8.2300+05
  KG/DAY              3.5587+05
  L/DAY               4.8299+05
STATE VARIABLES:
  TEMP   C              58.8310
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL               -285.9187
  J/KG                -1.5869+07
  KW                  -6.5364+04
ENTROPY:
  CAL/MOL-K             -38.5982
  CAL/GM-K               -2.1423
DENSITY:
  MOL/CC               4.0895-02
  GM/CC                   0.7368
AVG MW                   18.0170

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

S20
---

STREAM ID               S20
FROM :                  CHROMA
TO   :                  EVAP

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               3.0202+05
  GLUCOSE                0.0
  XYLOSE               488.7400
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL             3182.3591
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              3.0569+05
  KG/DAY              1.4396+05
  L/DAY               1.8500+05
STATE VARIABLES:
  TEMP   C              32.0000
```

```
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -297.0912
  J/KG               -1.5140+07
  KW                 -2.5227+04
ENTROPY:
  CAL/MOL-K            -42.2578
  CAL/GM-K              -2.1535
DENSITY:
  MOL/CC              3.9657-02
  GM/CC                  0.7782
AVG MW                  19.6229

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                    0.0      $/KG                   0.0
CAOH                                   0.1760   $/KG                  54.1832
ENZYMES                                0.5070   $/KG                 331.0499
LIQUOR                                 0.0      $/KG                   0.0
NACIT                                  1.9180   $/KG                 415.6513
NH3                                    0.3000   $/KG                 374.8750
PREC-PLA                               0.0      $/KG                   0.0
PREC-XYL                               0.0      $/KG                   0.0
PURE                                   0.0      $/KG                   0.0
SA-IN                                  0.2756   $/KG                  26.9951
STEAM3                                 0.0      $/KG                   0.0
STEAM4                                 0.0      $/KG                   0.0
XYLITOL                                1.4330   $/KG                 589.7120

S21
---

STREAM ID               S21
FROM :                  B15
TO   :                  PLA-FERM

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER              8.1648+05
  GLUCOSE            3539.5017
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR             8.2002+05
  KG/DAY             3.6832+05
  L/DAY              4.8146+05
STATE VARIABLES:
  TEMP   C              37.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -292.1135
  J/KG               -1.5608+07
  KW                 -6.6539+04
ENTROPY:
  CAL/MOL-K            -40.9755
  CAL/GM-K              -2.1894
DENSITY:
  MOL/CC              4.0877-02
  GM/CC                  0.7650
AVG MW                  18.7151

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                    2.0027
BSG                                    0.0      $/KG                   0.0
CAOH                                   0.1760   $/KG                  54.1832
ENZYMES                                0.5070   $/KG                 331.0499
LIQUOR                                 0.0      $/KG                   0.0
NACIT                                  1.9180   $/KG                 415.6513
NH3                                    0.3000   $/KG                 374.8750
PREC-PLA                               0.0      $/KG                   0.0
PREC-XYL                               0.0      $/KG                   0.0
PURE                                   0.0      $/KG                   0.0
SA-IN                                  0.2756   $/KG                  26.9951
STEAM3                                 0.0      $/KG                   0.0
STEAM4                                 0.0      $/KG                   0.0
XYLITOL                                1.4330   $/KG                 589.7120

S22
---

STREAM ID               S22
FROM :                  B13
TO   :                  B10

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER              3.5305+05
  GLUCOSE                0.0
  XYLOSE             2.3098-02
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID              85.5711
  CELLULOS           5.5705-04
  ENZ/XYL                0.1081
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER            3.4511-05
  N2                     0.0
```

```
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR              3.5313+05
  KG/DAY              1.5272+05
  L/DAY               2.1546+05
STATE VARIABLES:
  TEMP   C             102.4441
  PRES   ATM             1.0000
  VFRAC                 0.0
  LFRAC                  1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL              -282.1051
  J/KG               -1.5656+07
  KW                 -2.7672+04
ENTROPY:
  CAL/MOL-K            -36.0294
  CAL/GM-K              -1.9995
DENSITY:
  MOL/CC              3.9336-02
  GM/CC                  0.7088
AVG MW                  18.0192
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S23
---

```
STREAM ID               S23
FROM :                  B16
TO   :                  XLAFERM

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               3.0202+05
  GLUCOSE                4.2792
  XYLOSE              3838.2129
  AMMONIA               0.0
  OTHLIQUI            6.2002+04
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL             238.6606
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR              3.6810+05
  KG/DAY              1.7510+05
  L/DAY               2.2110+05
STATE VARIABLES:
  TEMP   C              32.0000
  PRES   ATM             1.0000
  VFRAC                 0.0
  LFRAC                  1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL              -297.5477
  J/KG               -1.5012+07
  KW                 -3.0424+04
ENTROPY:
  CAL/MOL-K            -41.5442
  CAL/GM-K              -2.0960
DENSITY:
  MOL/CC              3.9957-02
  GM/CC                  0.7920
AVG MW                  19.8206
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S24
---

```
STREAM ID               S24
FROM :                  B17
TO   :                  PLAFLASH

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               4736.6659
  GLUCOSE               32.1775
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
```

```
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             9781.2581
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    5.6034
TOTAL FLOW:
  MOL/HR              1.4556+04
  KG/DAY              5.2804+04
  L/DAY               1.5779+07
STATE VARIABLES:
  TEMP   C             288.0000
  PRES   ATM             1.0000
  VFRAC                  0.9994
  LFRAC               5.7320-04
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL                 0.3588
  J/KG                2373.7262
  KW                     1.4507
ENTROPY:
  CAL/MOL-K            -42.7536
  CAL/GM-K              -0.2828
DENSITY:
  MOL/CC              2.2139-05
  GM/CC               3.3465-03
AVG MW                 151.1560

STREAM COSTS
------------

ID                                 PRICE                          COST $/HR
-----------                        -----------------------------  ------------
AASWAT                              7.2647-04   $/L                   2.0027
BSG                                    0.0      $/KG                  0.0
CAOH                                   0.1760   $/KG                 54.1832
ENZYMES                                0.5070   $/KG                331.0499
LIQUOR                                 0.0      $/KG                  0.0
NACIT                                  1.9180   $/KG                415.6513
NH3                                    0.3000   $/KG                374.8750
PREC-PLA                               0.0      $/KG                  0.0
PREC-XYL                               0.0      $/KG                  0.0
PURE                                   0.0      $/KG                  0.0
SA-IN                                  0.2756   $/KG                 26.9951
STEAM3                                 0.0      $/KG                  0.0
STEAM4                                 0.0      $/KG                  0.0
XYLITOL                                1.4330   $/KG                589.7120

S25
---

STREAM ID               S25
FROM :                  B22
TO   :                  B16

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               3.0202+05
  GLUCOSE                4.2792
  XYLOSE              3838.2129
  AMMONIA                0.0
  OTHLIQUI            6.2002+04
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL              238.6606
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              3.6810+05
  KG/DAY              1.7510+05
  L/DAY               2.2035+05
STATE VARIABLES:
  TEMP   C              27.2171
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -297.9740
  J/KG               -1.5034+07
  KW                 -3.0468+04
ENTROPY:
  CAL/MOL-K            -41.8805
  CAL/GM-K              -2.1130
DENSITY:
  MOL/CC              4.0092-02
  GM/CC                  0.7946
AVG MW                  19.8206

STREAM COSTS
------------

ID                                 PRICE                          COST $/HR
-----------                        -----------------------------  ------------
AASWAT                              7.2647-04   $/L                   2.0027
BSG                                    0.0      $/KG                  0.0
CAOH                                   0.1760   $/KG                 54.1832
ENZYMES                                0.5070   $/KG                331.0499
LIQUOR                                 0.0      $/KG                  0.0
NACIT                                  1.9180   $/KG                415.6513
NH3                                    0.3000   $/KG                374.8750
PREC-PLA                               0.0      $/KG                  0.0
PREC-XYL                               0.0      $/KG                  0.0
PURE                                   0.0      $/KG                  0.0
SA-IN                                  0.2756   $/KG                 26.9951
STEAM3                                 0.0      $/KG                  0.0
STEAM4                                 0.0      $/KG                  0.0
XYLITOL                                1.4330   $/KG                589.7120

S26
---

STREAM ID               S26
FROM :                  B20
```

```
TO   :                  B1

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER               1.0509+06
  GLUCOSE                4.1938
  XYLOSE              2.3109-02
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS            1.4330+04
  ENZ/XYL                0.1082
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             3.1610-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              1.0652+06
  KG/DAY              5.1633+05
  L/DAY               8.4619+08
STATE VARIABLES:
  TEMP   C             140.0000
  PRES   ATM             1.0000
  VFRAC                  0.9826
  LFRAC               1.7439-02
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL               -251.2037
  J/KG               -1.2438+07
  KW                 -7.4328+04
ENTROPY:
  CAL/MOL-K             -11.3258
  CAL/GM-K               -0.5608
DENSITY:
  MOL/CC              3.0211-05
  GM/CC               6.1018-04
AVG MW                  20.1972

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04    $/L                  2.0027
BSG                                    0.0       $/KG                 0.0
CAOH                                   0.1760    $/KG                54.1832
ENZYMES                                0.5070    $/KG               331.0499
LIQUOR                                 0.0       $/KG                 0.0
NACIT                                  1.9180    $/KG               415.6513
NH3                                    0.3000    $/KG               374.8750
PREC-PLA                               0.0       $/KG                 0.0
PREC-XYL                               0.0       $/KG                 0.0
PURE                                   0.0       $/KG                 0.0
SA-IN                                  0.2756    $/KG                26.9951
STEAM3                                 0.0       $/KG                 0.0
STEAM4                                 0.0       $/KG                 0.0
XYLITOL                                1.4330    $/KG               589.7120
```

```
S27
---

STREAM ID               S27
FROM :                  B12
TO   :                  ----

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                  0.0
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID            1639.1820
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              1639.1820
  KG/DAY              1338.1500
  L/DAY               1055.1884
STATE VARIABLES:
  TEMP   C              32.0000
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL               -191.3770
  J/KG               -5.6263+06
  KW                    -87.1394
ENTROPY:
  CAL/MOL-K             -56.0912
  CAL/GM-K               -1.6490
DENSITY:
  MOL/CC              3.7283-02
  GM/CC                  1.2682
AVG MW                  34.0147

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04    $/L                  2.0027
BSG                                    0.0       $/KG                 0.0
CAOH                                   0.1760    $/KG                54.1832
ENZYMES                                0.5070    $/KG               331.0499
LIQUOR                                 0.0       $/KG                 0.0
NACIT                                  1.9180    $/KG               415.6513
NH3                                    0.3000    $/KG               374.8750
PREC-PLA                               0.0       $/KG                 0.0
PREC-XYL                               0.0       $/KG                 0.0
PURE                                   0.0       $/KG                 0.0
```

| | | | |
|---|---|---|---|
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S28
---

```
STREAM ID               S28
FROM :                  B12
TO   :                  CHROMA

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               3.0202+05
  GLUCOSE               0.0
  XYLOSE              488.7400
  AMMONIA               0.0
  OTHLIQUI            6.2002+04
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL             3182.3591
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR              3.6769+05
  KG/DAY              1.7377+05
  L/DAY               2.2108+05
STATE VARIABLES:
  TEMP   C              32.0000
  PRES   ATM             1.0000
  VFRAC                 0.0
  LFRAC                  1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL              -296.9659
  J/KG               -1.5081+07
  KW                 -3.0331+04
ENTROPY:
  CAL/MOL-K            -41.2836
  CAL/GM-K              -2.0966
DENSITY:
  MOL/CC              3.9915-02
  GM/CC                  0.7860
AVG MW                  19.6911
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S29
---

```
STREAM ID               S29
FROM :                  B21
TO   :                  B5

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               8.2291+05
  GLUCOSE             5.8149-03
  XYLOSE              2.3098-02
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS            5.5705-04
  ENZ/XYL               0.1081
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER             4.5375-05
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR              8.2292+05
  KG/DAY              3.5580+05
  L/DAY               4.8293+05
STATE VARIABLES:
  TEMP   C              58.8310
  PRES   ATM             1.0000
  VFRAC                 0.0
  LFRAC                  1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL              -285.9288
  J/KG               -1.5871+07
  KW                 -6.5360+04
ENTROPY:
  CAL/MOL-K            -38.5986
  CAL/GM-K              -2.1425
DENSITY:
  MOL/CC              4.0896-02
  GM/CC                  0.7367
AVG MW                  18.0153
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|

| | | | |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S30
---

| | |
|---|---|
| STREAM ID | S30 |
| FROM : | B21 |
| TO : | ---- |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 85.5711 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 85.5711 |
| KG/DAY | 69.8562 |
| L/DAY | 55.9439 |
| STATE VARIABLES: | |
| TEMP C | 58.8310 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -188.7454 |
| J/KG | -5.5489+06 |
| KW | -4.4864 |
| ENTROPY: | |
| CAL/MOL-K | -54.1170 |
| CAL/GM-K | -1.5910 |
| DENSITY: | |
| MOL/CC | 3.6710-02 |
| GM/CC | 1.2487 |
| AVG MW | 34.0147 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

S31
---

| | |
|---|---|
| STREAM ID | S31 |
| FROM : | LLE |
| TO : | LLEREC |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 8.1559+05 |
| GLUCOSE | 32.1768 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 4152.5822 |
| DIETHER | 5.3221-08 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 8.1978+05 |
| KG/DAY | 3.6175+05 |
| L/DAY | 4.7597+05 |
| STATE VARIABLES: | |
| TEMP C | 22.7000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -291.0845 |
| J/KG | -1.5831+07 |
| KW | -6.6285+04 |
| ENTROPY: | |
| CAL/MOL-K | -43.4061 |
| CAL/GM-K | -2.3607 |

```
DENSITY:
  MOL/CC             4.1336-02
  GM/CC                 0.7600
AVG MW                 18.3867

STREAM COSTS
------------

ID                                 PRICE                              COST $/HR
-----------                        -----------------------------      ------------
AASWAT                              7.2647-04   $/L                       2.0027
BSG                                    0.0      $/KG                      0.0
CAOH                                   0.1760   $/KG                     54.1832
ENZYMES                                0.5070   $/KG                    331.0499
LIQUOR                                 0.0      $/KG                      0.0
NACIT                                  1.9180   $/KG                    415.6513
NH3                                    0.3000   $/KG                    374.8750
PREC-PLA                               0.0      $/KG                      0.0
PREC-XYL                               0.0      $/KG                      0.0
PURE                                   0.0      $/KG                      0.0
SA-IN                                  0.2756   $/KG                     26.9951
STEAM3                                 0.0      $/KG                      0.0
STEAM4                                 0.0      $/KG                      0.0
XYLITOL                                1.4330   $/KG                    589.7120

S32
---

STREAM ID               S32
FROM :                  LLEREC
TO   :                  B25

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                    0.0
  GLUCOSE                 32.1768
  XYLOSE                   0.0
  AMMONIA                  0.0
  OTHLIQUI                 0.0
  H2SO4                    0.0
  CAOH2                    0.0
  CASO4                    0.0
  OTHSOLID                 0.0
  CELLULOS                 0.0
  ENZ/XYL                  0.0
  NACIT                    0.0
  LACTICAC              3944.9531
  DIETHER               5.3221-08
  N2                       0.0
  METHANOL                 0.0
  CH2CL2                   0.0
  ETHYL-01                 0.0
  PLA                      0.0
TOTAL FLOW:
  MOL/HR                3977.1299
  KG/DAY                8667.6887
  L/DAY                 9147.5599
STATE VARIABLES:
  TEMP   C                22.7000
  PRES   ATM               1.0000
  VFRAC                    0.0
  LFRAC                    1.0000
  SFRAC                    0.0
ENTHALPY:
  KJ/MOL                -709.1282
  J/KG                 -7.8091+06
  KW                    -783.4153
ENTROPY:
  CAL/MOL-K             -536.0210
  CAL/GM-K                -5.9028
DENSITY:
  MOL/CC                1.0435-02
  GM/CC                    0.9475
AVG MW                    90.8076

STREAM COSTS
------------

ID                                 PRICE                              COST $/HR
-----------                        -----------------------------      ------------
AASWAT                              7.2647-04   $/L                       2.0027
BSG                                    0.0      $/KG                      0.0
CAOH                                   0.1760   $/KG                     54.1832
ENZYMES                                0.5070   $/KG                    331.0499
LIQUOR                                 0.0      $/KG                      0.0
NACIT                                  1.9180   $/KG                    415.6513
NH3                                    0.3000   $/KG                    374.8750
PREC-PLA                               0.0      $/KG                      0.0
PREC-XYL                               0.0      $/KG                      0.0
PURE                                   0.0      $/KG                      0.0
SA-IN                                  0.2756   $/KG                     26.9951
STEAM3                                 0.0      $/KG                      0.0
STEAM4                                 0.0      $/KG                      0.0
XYLITOL                                1.4330   $/KG                    589.7120

S33
---

STREAM ID               S33
FROM :                  LLE
TO   :                  B25

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                  887.7925
  GLUCOSE               5.0133-04
  XYLOSE                   0.0
  AMMONIA                  0.0
  OTHLIQUI                 0.0
  H2SO4                    0.0
  CAOH2                    0.0
  CASO4                    0.0
  OTHSOLID                 0.0
  CELLULOS                 0.0
  ENZ/XYL                  0.0
  NACIT                    0.0
  LACTICAC              2218.5209
  DIETHER               9791.7798
  N2                       0.0
  METHANOL                 0.0
  CH2CL2                   0.0
  ETHYL-01                 0.0
  PLA                      0.0
TOTAL FLOW:
  MOL/HR                1.2898+04
  KG/DAY                4.5180+04
  L/DAY                 5.1873+04
STATE VARIABLES:
  TEMP   C                34.5000
  PRES   ATM               1.0000
```

```
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -145.5361
  J/KG                 -9.9715+05
  KW                   -521.4274
ENTROPY:
  CAL/MOL-K            -189.3347
  CAL/GM-K               -1.2972
DENSITY:
  MOL/CC                5.9676-03
  GM/CC                   0.8710
AVG MW                  145.9520

STREAM COSTS
------------

ID                                  PRICE                           COST $/HR
-----------                         -----------------------------   ------------
AASWAT                               7.2647-04   $/L                     2.0027
BSG                                     0.0      $/KG                    0.0
CAOH                                    0.1760   $/KG                   54.1832
ENZYMES                                 0.5070   $/KG                  331.0499
LIQUOR                                  0.0      $/KG                    0.0
NACIT                                   1.9180   $/KG                  415.6513
NH3                                     0.3000   $/KG                  374.8750
PREC-PLA                                0.0      $/KG                    0.0
PREC-XYL                                0.0      $/KG                    0.0
PURE                                    0.0      $/KG                    0.0
SA-IN                                   0.2756   $/KG                   26.9951
STEAM3                                  0.0      $/KG                    0.0
STEAM4                                  0.0      $/KG                    0.0
XYLITOL                                 1.4330   $/KG                  589.7120

S34
---

STREAM ID               S34
FROM :                  B23
TO   :                  COOL2

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                 2.6898+04
  GLUCOSE                 0.0
  XYLOSE                488.6902
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL              3182.0769
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR                3.0569+04
```

```
  KG/DAY                2.5010+04
  L/DAY                 2.6881+04
STATE VARIABLES:
  TEMP   C               45.9187
  PRES   ATM              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -376.6121
  J/KG                 -1.1048+07
  KW                  -3197.9744
ENTROPY:
  CAL/MOL-K             -59.5963
  CAL/GM-K               -1.7482
DENSITY:
  MOL/CC                2.7293-02
  GM/CC                   0.9304
AVG MW                   34.0897

STREAM COSTS
------------

ID                                  PRICE                           COST $/HR
-----------                         -----------------------------   ------------
AASWAT                               7.2647-04   $/L                     2.0027
BSG                                     0.0      $/KG                    0.0
CAOH                                    0.1760   $/KG                   54.1832
ENZYMES                                 0.5070   $/KG                  331.0499
LIQUOR                                  0.0      $/KG                    0.0
NACIT                                   1.9180   $/KG                  415.6513
NH3                                     0.3000   $/KG                  374.8750
PREC-PLA                                0.0      $/KG                    0.0
PREC-XYL                                0.0      $/KG                    0.0
PURE                                    0.0      $/KG                    0.0
SA-IN                                   0.2756   $/KG                   26.9951
STEAM3                                  0.0      $/KG                    0.0
STEAM4                                  0.0      $/KG                    0.0
XYLITOL                                 1.4330   $/KG                  589.7120

S36
---

STREAM ID               S36
FROM :                  B23
TO   :                  SPLIT

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER                 2.1519+04
  GLUCOSE                 0.0
  XYLOSE                488.7000
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL               477.3211
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
```

```
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             2.2485+04
  KG/DAY             1.2808+04
  L/DAY              1.5977+04
STATE VARIABLES:
  TEMP   C             95.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -313.6615
  J/KG              -1.3216+07
  KW                -1959.1032
ENTROPY:
  CAL/MOL-K           -43.2539
  CAL/GM-K             -1.8224
DENSITY:
  MOL/CC             3.3776-02
  GM/CC                 0.8016
AVG MW                 23.7341

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

SA-IN
-----

STREAM ID               SA-IN
FROM :                  ----
TO   :                  B8

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER              2312.8515
  GLUCOSE               0.0
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4               573.9393
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.0
```

```
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
COST:
  $/HR                 26.9951
TOTAL FLOW:
  MOL/HR             2886.7907
  KG/DAY             2351.0000
  L/DAY              2857.2687
STATE VARIABLES:
  TEMP   C             25.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -401.1851
  J/KG              -1.1823+07
  KW                 -321.7049
ENTROPY:
  CAL/MOL-K           -54.5391
  CAL/GM-K             -1.6072
DENSITY:
  MOL/CC             2.4248-02
  GM/CC                 0.8228
AVG MW                 33.9333

STREAM COSTS
------------

ID                                 PRICE                           COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

SACHIN
------

STREAM ID               SACHIN
FROM :                  WASH2
TO   :                  SACCH

SUBSTREAM: MIXED
PHASE:                  MIXED
COMPONENTS: MOL/HR
  WATER              8.5945+05
  GLUCOSE               0.0
  XYLOSE                0.0
  AMMONIA            9983.5910
```

```
  OTHLIQUI            3.1840+04
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID            4695.8931
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              9.0597+05
  KG/DAY              3.9913+05
  L/DAY               8.5159+06
STATE VARIABLES:
  TEMP   C              64.7913
  PRES   ATM             1.0000
  VFRAC               1.3854-02
  LFRAC                  0.9861
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -285.9382
  J/KG               -1.5577+07
  KW                 -7.1959+04
ENTROPY:
  CAL/MOL-K            -40.6996
  CAL/GM-K              -2.2172
DENSITY:
  MOL/CC              2.5533-03
  GM/CC               4.6869-02
AVG MW                  18.3566

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

STEAM1
------

STREAM ID                STEAM1
FROM :                   ETHFLASH
TO   :                   B3

SUBSTREAM: MIXED
PHASE:                   VAPOR
COMPONENTS: MOL/HR
  WATER               4126.5819
  GLUCOSE             5.8074-03
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER              233.9249
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              4360.5126
  KG/DAY              2739.8187
  L/DAY               3.6715+06
STATE VARIABLES:
  TEMP   C             157.4842
  PRES   ATM             1.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -220.3544
  J/KG               -8.4168+06
  KW                  -266.9050
ENTROPY:
  CAL/MOL-K            -11.1250
  CAL/GM-K              -0.4249
DENSITY:
  MOL/CC              2.8504-05
  GM/CC               7.4623-04
AVG MW                  26.1802

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------   ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

STEAM2
------

STREAM ID                STEAM2
```

```
FROM :                  DRYPLA
TO   :                  B3

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: MOL/HR
  WATER               2313.9709
  GLUCOSE             1.0454-05
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                8.6511
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                 9.5277-24
TOTAL FLOW:
  MOL/HR              2322.6220
  KG/DAY              1035.8243
  L/DAY               1.6915+06
STATE VARIABLES:
  TEMP   C              99.8609
  PRES   ATM             1.0000
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -238.2231
  J/KG               -1.2820+07
  KW                  -153.6951
ENTROPY:
  CAL/MOL-K             -9.0810
  CAL/GM-K              -0.4887
DENSITY:
  MOL/CC              3.2956-05
  GM/CC               6.1239-04
AVG MW                  18.5822

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
STEAM3
------

STREAM ID               STEAM3
FROM :                  EVAP2
TO   :                  B6

SUBSTREAM: MIXED
PHASE:                  VAPOR
COMPONENTS: MOL/HR
  WATER               7.7926+04
  GLUCOSE                0.0
  XYLOSE                 0.0
  AMMONIA                0.0
  OTHLIQUI               0.0
  H2SO4                  0.0
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID              85.5712
  CELLULOS            5.5705-04
  ENZ/XYL             3.5645-07
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER             4.7257-05
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
COST:
  $/HR                   0.0
TOTAL FLOW:
  MOL/HR              7.8012+04
  KG/DAY              3.3762+04
  L/DAY               4.4841+07
STATE VARIABLES:
  TEMP   C             110.0000
  PRES   ATM             1.2993
  VFRAC                  1.0000
  LFRAC                  0.0
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -238.9171
  J/KG               -1.3249+07
  KW                 -5177.3053
ENTROPY:
  CAL/MOL-K             -9.1396
  CAL/GM-K              -0.5068
DENSITY:
  MOL/CC              4.1753-05
  GM/CC               7.5293-04
AVG MW                  18.0328

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |

| | | | |
|---|---|---|---|
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

STEAM4
------

```
STREAM ID              STEAM4
FROM :                 EVAP
TO   :                 B19

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: MOL/HR
  WATER              2.7512+05
  GLUCOSE               0.0
  XYLOSE             2.3098-02
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.1081
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
COST:
  $/HR                  0.0
TOTAL FLOW:
  MOL/HR             2.7512+05
  KG/DAY             1.1895+05
  L/DAY              2.0228+08
STATE VARIABLES:
  TEMP   C            103.3036
  PRES   ATM            1.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -239.2434
  J/KG               -1.3280+07
  KW                 -1.8284+04
ENTROPY:
  CAL/MOL-K            -8.7585
  CAL/GM-K             -0.4862
DENSITY:
  MOL/CC             3.2642-05
  GM/CC              5.8806-04
AVG MW                 18.0153
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

STEAM5
------

```
STREAM ID              STEAM5
FROM :                 B19
TO   :                 B6

SUBSTREAM: MIXED
PHASE:                 VAPOR
COMPONENTS: MOL/HR
  WATER              2.7512+05
  GLUCOSE               0.0
  XYLOSE             2.3098-02
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.1081
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER               0.0
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             2.7512+05
  KG/DAY             1.1895+05
  L/DAY              2.3075+08
STATE VARIABLES:
  TEMP   C            155.2010
  PRES   ATM            1.0000
  VFRAC                 1.0000
  LFRAC                 0.0
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -237.4522
  J/KG               -1.3181+07
  KW                 -1.8147+04
ENTROPY:
  CAL/MOL-K            -7.6939
  CAL/GM-K             -0.4271
DENSITY:
  MOL/CC             2.8615-05
  GM/CC              5.1550-04
AVG MW                 18.0153
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

STOUT
-----

| | |
|---|---|
| STREAM ID | STOUT |
| FROM : | B2 |
| TO : | WATPUR |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 6440.5528 |
| GLUCOSE | 5.8179-03 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 242.5760 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 9.5277-24 |
| TOTAL FLOW: | |
| MOL/HR | 6683.1346 |
| KG/DAY | 3775.6430 |
| L/DAY | 4.4087+05 |
| STATE VARIABLES: | |
| TEMP C | 90.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 9.4773-02 |
| LFRAC | 0.9052 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -268.0753 |
| J/KG | -1.1388+07 |
| KW | -497.6620 |
| ENTROPY: | |
| CAL/MOL-K | -36.9156 |
| CAL/GM-K | -1.5682 |

| | |
|---|---|
| DENSITY: | |
| MOL/CC | 3.6382-04 |
| GM/CC | 8.5641-03 |
| AVG MW | 23.5396 |

STREAM COSTS
------------


| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |


SUGARSP
-------

| | |
|---|---|
| STREAM ID | SUGARSP |
| FROM : | SACCH |
| TO : | FUGEPLA |
| SUBSTREAM: MIXED | |
| PHASE: | MIXED |
| COMPONENTS: MOL/HR | |
| WATER | 8.5945+05 |
| GLUCOSE | 3539.5017 |
| XYLOSE | 0.0 |
| AMMONIA | 9983.5910 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 4695.8931 |
| CELLULOS | 0.0 |
| ENZ/XYL | 4291.6202 |
| NACIT | 3708.0625 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 8.8567+05 |
| KG/DAY | 4.2001+05 |
| L/DAY | 6.0247+06 |
| STATE VARIABLES: | |
| TEMP C | 25.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 1.1531-02 |
| LFRAC | 0.9885 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -297.4390 |

```
  J/KG              -1.5053+07
  KW                -7.3176+04
ENTROPY:
  CAL/MOL-K           -45.3638
  CAL/GM-K             -2.2958
DENSITY:
  MOL/CC             3.5282-03
  GM/CC              6.9714-02
AVG MW                 19.7593

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------    ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

SUGARSX
-------

STREAM ID               SUGARSX
FROM :                  CAOH-NEU
TO   :                  FUGEXYL

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               2.9720+05
  GLUCOSE                4.2792
  XYLOSE              3593.8629
  AMMONIA                 0.0
  OTHLIQUI            6.2002+04
  H2SO4                 32.9029
  CAOH2                 28.4756
  CASO4                541.0364
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL                 0.0
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR              3.6341+05
  KG/DAY              1.7317+05
  L/DAY               2.2045+05
STATE VARIABLES:
  TEMP   C              25.0000
  PRES   ATM             1.0000
```

```
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -298.9470
  J/KG                -1.5057+07
  KW                  -3.0177+04
ENTROPY:
  CAL/MOL-K             -43.3553
  CAL/GM-K               -2.1836
DENSITY:
  MOL/CC               3.9564-02
  GM/CC                   0.7855
AVG MW                   19.8545

STREAM COSTS
------------

ID                                 PRICE                            COST $/HR
-----------                        -----------------------------    ------------
AASWAT                              7.2647-04   $/L                     2.0027
BSG                                    0.0      $/KG                    0.0
CAOH                                   0.1760   $/KG                   54.1832
ENZYMES                                0.5070   $/KG                  331.0499
LIQUOR                                 0.0      $/KG                    0.0
NACIT                                  1.9180   $/KG                  415.6513
NH3                                    0.3000   $/KG                  374.8750
PREC-PLA                               0.0      $/KG                    0.0
PREC-XYL                               0.0      $/KG                    0.0
PURE                                   0.0      $/KG                    0.0
SA-IN                                  0.2756   $/KG                   26.9951
STEAM3                                 0.0      $/KG                    0.0
STEAM4                                 0.0      $/KG                    0.0
XYLITOL                                1.4330   $/KG                  589.7120

WASTE
-----

STREAM ID               WASTE
FROM :                  LLEREC
TO   :                  ----

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               8.1559+05
  GLUCOSE                 0.0
  XYLOSE                  0.0
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS                0.0
  ENZ/XYL                 0.0
  NACIT                   0.0
  LACTICAC              207.6291
  DIETHER                 0.0
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR              8.1580+05
```

```
  KG/DAY             3.5308+05
  L/DAY              4.6637+05
STATE VARIABLES:
  TEMP   C             22.7000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -289.1608
  J/KG              -1.6035+07
  KW                -6.5527+04
ENTROPY:
  CAL/MOL-K           -41.1044
  CAL/GM-K             -2.2793
DENSITY:
  MOL/CC             4.1982-02
  GM/CC                 0.7571
AVG MW                 18.0336
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

WATER1
------

```
STREAM ID              WATER1
FROM :                 WATPUR
TO   :                 B10

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER              6395.5466
  GLUCOSE            5.8149-03
  XYLOSE                0.0
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS              0.0
  ENZ/XYL               0.0
  NACIT                 0.0
  LACTICAC              0.0
  DIETHER            1.0864-05
  N2                    0.0
  METHANOL              0.0
  CH2CL2                0.0
  ETHYL-01              0.0
  PLA                   0.0
TOTAL FLOW:
  MOL/HR             6395.5524
  KG/DAY             2765.2467
  L/DAY              3855.9400
STATE VARIABLES:
  TEMP   C             90.0000
  PRES   ATM            1.0000
  VFRAC                 0.0
  LFRAC                 1.0000
  SFRAC                 0.0
ENTHALPY:
  KJ/MOL             -283.2188
  J/KG              -1.5721+07
  KW                 -503.1501
ENTROPY:
  CAL/MOL-K           -36.7348
  CAL/GM-K             -2.0391
DENSITY:
  MOL/CC             3.9807-02
  GM/CC                 0.7171
AVG MW                 18.0154
```

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

WETBSGC
-------

```
STREAM ID              WETBSGC
FROM :                 WASH
TO   :                 B20

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER              1.0509+06
  GLUCOSE               4.1938
  XYLOSE             2.3109-02
  AMMONIA               0.0
  OTHLIQUI              0.0
  H2SO4                 0.0
  CAOH2                 0.0
  CASO4                 0.0
  OTHSOLID              0.0
  CELLULOS           1.4330+04
  ENZ/XYL               0.1082
```

```
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER              3.1610-05
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR               1.0652+06
  KG/DAY               5.1633+05
  L/DAY                6.7532+05
STATE VARIABLES:
  TEMP   C               75.9008
  PRES   ATM              1.0000
  VFRAC                   0.0
  LFRAC                   1.0000
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -296.9584
  J/KG                -1.4703+07
  KW                  -8.7866+04
ENTROPY:
  CAL/MOL-K             -40.3760
  CAL/GM-K               -1.9991
DENSITY:
  MOL/CC               3.7855-02
  GM/CC                   0.7646
AVG MW                   20.1972

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
WETBSGH
-------

STREAM ID              WETBSGH
FROM :                 B1
TO   :                 SA-HYDRO

SUBSTREAM: MIXED
PHASE:                 MIXED
COMPONENTS: MOL/HR
  WATER                1.0509+06
  GLUCOSE                 4.1938
  XYLOSE               2.3109-02
  AMMONIA                 0.0
  OTHLIQUI                0.0
  H2SO4                   0.0
  CAOH2                   0.0
  CASO4                   0.0
  OTHSOLID                0.0
  CELLULOS             1.4330+04
  ENZ/XYL                 0.1082
  NACIT                   0.0
  LACTICAC                0.0
  DIETHER              3.1610-05
  N2                      0.0
  METHANOL                0.0
  CH2CL2                  0.0
  ETHYL-01                0.0
  PLA                     0.0
TOTAL FLOW:
  MOL/HR               1.0652+06
  KG/DAY               5.1633+05
  L/DAY                8.6802+08
STATE VARIABLES:
  TEMP   C              150.0000
  PRES   ATM              1.0000
  VFRAC                   0.9837
  LFRAC                1.6327-02
  SFRAC                   0.0
ENTHALPY:
  KJ/MOL               -250.7606
  J/KG                -1.2416+07
  KW                  -7.4197+04
ENTROPY:
  CAL/MOL-K             -11.0727
  CAL/GM-K               -0.5482
DENSITY:
  MOL/CC               2.9452-05
  GM/CC                5.9484-04
AVG MW                   20.1972

STREAM COSTS
------------
```

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
X1
--

STREAM ID              X1
FROM :                 B18
TO   :                 ----

SUBSTREAM: MIXED
PHASE:                 LIQUID
COMPONENTS: MOL/HR
  WATER                4.2623-02
```

GLUCOSE 1.8696-02
XYLOSE 0.0
AMMONIA 0.0
OTHLIQUI 0.0
H2SO4 0.0
CAOH2 0.0
CASO4 0.0
OTHSOLID 0.0
CELLULOS 0.0
ENZ/XYL 0.0
NACIT 0.0
LACTICAC 0.0
DIETHER 2.6769
N2 0.0
METHANOL 4.6971+04
CH2CL2 1.6256+04
ETHYL-01 0.0
PLA 0.0
TOTAL FLOW:
MOL/HR 6.3230+04
KG/DAY 6.9268+04
L/DAY 9.2960+04
STATE VARIABLES:
TEMP C 55.1613
PRES ATM 1.0000
VFRAC 0.0
LFRAC 1.0000
SFRAC 0.0
ENTHALPY:
KJ/MOL -208.1253
J/KG -4.5596+06
KW -3655.4916
ENTROPY:
CAL/MOL-K -51.9384
CAL/GM-K -1.1379
DENSITY:
MOL/CC 1.6325-02
GM/CC 0.7451
AVG MW 45.6458

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

X2
--

STREAM ID X2
FROM : B18
TO : ----

SUBSTREAM: MIXED
PHASE: LIQUID
COMPONENTS: MOL/HR
WATER 1.7063-03
GLUCOSE 7.6413-08
XYLOSE 0.0
AMMONIA 0.0
OTHLIQUI 0.0
H2SO4 0.0
CAOH2 0.0
CASO4 0.0
OTHSOLID 0.0
CELLULOS 0.0
ENZ/XYL 0.0
NACIT 0.0
LACTICAC 0.0
DIETHER 1.0941-05
N2 0.0
METHANOL 47.0182
CH2CL2 2.2991+04
ETHYL-01 0.0
PLA 0.0
TOTAL FLOW:
MOL/HR 2.3038+04
KG/DAY 4.6900+04
L/DAY 4.2010+04
STATE VARIABLES:
TEMP C 40.1463
PRES ATM 1.0000
VFRAC 0.0
LFRAC 1.0000
SFRAC 0.0
ENTHALPY:
KJ/MOL -123.1558
J/KG -1.4519+06
KW -788.1246
ENTROPY:
CAL/MOL-K -42.1090
CAL/GM-K -0.4964
DENSITY:
MOL/CC 1.3162-02
GM/CC 1.1164
AVG MW 84.8243

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

XYLITOL

-------

| | |
|---|---|
| STREAM ID | XYLITOL |
| FROM : | CRYSTALL |
| TO : | ---- |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 0.0 |
| GLUCOSE | 0.0 |
| XYLOSE | 0.0 |
| AMMONIA | 0.0 |
| OTHLIQUI | 0.0 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 2704.7653 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| COST: | |
| $/HR | 589.7120 |
| TOTAL FLOW: | |
| MOL/HR | 2704.7653 |
| KG/DAY | 9876.5445 |
| L/DAY | 7977.8692 |
| STATE VARIABLES: | |
| TEMP C | 5.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -1068.0635 |
| J/KG | -7.0199+06 |
| KW | -802.4614 |
| ENTROPY: | |
| CAL/MOL-K | -232.0061 |
| CAL/GM-K | -1.5249 |
| DENSITY: | |
| MOL/CC | 8.1368-03 |
| GM/CC | 1.2380 |
| AVG MW | 152.1473 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

XYLSUGAR
--------

| | |
|---|---|
| STREAM ID | XYLSUGAR |
| FROM : | FUGEXYL |
| TO : | B22 |
| SUBSTREAM: MIXED | |
| PHASE: | LIQUID |
| COMPONENTS: MOL/HR | |
| WATER | 2.9126+05 |
| GLUCOSE | 4.2792 |
| XYLOSE | 3593.8629 |
| AMMONIA | 0.0 |
| OTHLIQUI | 6.2002+04 |
| H2SO4 | 0.0 |
| CAOH2 | 0.0 |
| CASO4 | 0.0 |
| OTHSOLID | 0.0 |
| CELLULOS | 0.0 |
| ENZ/XYL | 0.0 |
| NACIT | 0.0 |
| LACTICAC | 0.0 |
| DIETHER | 0.0 |
| N2 | 0.0 |
| METHANOL | 0.0 |
| CH2CL2 | 0.0 |
| ETHYL-01 | 0.0 |
| PLA | 0.0 |
| TOTAL FLOW: | |
| MOL/HR | 3.5686+05 |
| KG/DAY | 1.6870+05 |
| L/DAY | 2.1244+05 |
| STATE VARIABLES: | |
| TEMP C | 25.0000 |
| PRES ATM | 1.0000 |
| VFRAC | 0.0 |
| LFRAC | 1.0000 |
| SFRAC | 0.0 |
| ENTHALPY: | |
| KJ/MOL | -297.4797 |
| J/KG | -1.5103+07 |
| KW | -2.9488+04 |
| ENTROPY: | |
| CAL/MOL-K | -41.8685 |
| CAL/GM-K | -2.1256 |
| DENSITY: | |
| MOL/CC | 4.0315-02 |
| GM/CC | 0.7941 |
| AVG MW | 19.6973 |

STREAM COSTS
------------

| ID | PRICE | | COST $/HR |
|---|---|---|---|
| AASWAT | 7.2647-04 | $/L | 2.0027 |
| BSG | 0.0 | $/KG | 0.0 |
| CAOH | 0.1760 | $/KG | 54.1832 |
| ENZYMES | 0.5070 | $/KG | 331.0499 |

| | | | |
|---|---|---|---|
| LIQUOR | 0.0 | $/KG | 0.0 |
| NACIT | 1.9180 | $/KG | 415.6513 |
| NH3 | 0.3000 | $/KG | 374.8750 |
| PREC-PLA | 0.0 | $/KG | 0.0 |
| PREC-XYL | 0.0 | $/KG | 0.0 |
| PURE | 0.0 | $/KG | 0.0 |
| SA-IN | 0.2756 | $/KG | 26.9951 |
| STEAM3 | 0.0 | $/KG | 0.0 |
| STEAM4 | 0.0 | $/KG | 0.0 |
| XYLITOL | 1.4330 | $/KG | 589.7120 |

```
XYSUGARS
--------

STREAM ID               XYSUGARS
FROM :                  FILTER
TO   :                  CAOH-NEU

SUBSTREAM: MIXED
PHASE:                  LIQUID
COMPONENTS: MOL/HR
  WATER               2.8137+05
  GLUCOSE                4.2792
  XYLOSE              3593.8629
  AMMONIA                0.0
  OTHLIQUI            6.2002+04
  H2SO4                573.9393
  CAOH2                  0.0
  CASO4                  0.0
  OTHSOLID               0.0
  CELLULOS               0.0
  ENZ/XYL                0.0
  NACIT                  0.0
  LACTICAC               0.0
  DIETHER                0.0
  N2                     0.0
  METHANOL               0.0
  CH2CL2                 0.0
  ETHYL-01               0.0
  PLA                    0.0
TOTAL FLOW:
  MOL/HR              3.4755+05
  KG/DAY              1.6578+05
  L/DAY               2.2204+05
STATE VARIABLES:
  TEMP   C             102.7762
  PRES   ATM             1.0000
  VFRAC                  0.0
  LFRAC                  1.0000
  SFRAC                  0.0
ENTHALPY:
  KJ/MOL              -291.6674
  J/KG               -1.4675+07
  KW                 -2.8158+04
ENTROPY:
  CAL/MOL-K            -37.0445
  CAL/GM-K              -1.8639
DENSITY:
  MOL/CC              3.7566-02
  GM/CC                  0.7466
AVG MW                  19.8746
```

# Block Report

```
BLOCK:  AAS      MODEL: RYIELD
------------------------------
  INLET STREAMS:         NH3         4
  OUTLET STREAM:         AASPROD
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

    ***********************************************************************
    *                                                                     *
    *     ELEMENTS ARE NOT IN ATOM BALANCE                                *
    *                                                                     *
    ***********************************************************************

                   ***  MASS AND ENERGY BALANCE  ***
                           IN           OUT       GENERATION   RELATIVE DIFF.
  TOTAL BALANCE
  MOLE(MOL/HR  )         762029.       790329.       28300.3       0.00000
  MASS(KG/DAY  )         349133.       349133.                   -0.166720E-15
  ENTHALPY(KW      )    -60691.0      -62679.8                    0.317290E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE C                                  70.0000
  SPECIFIED PRESSURE    ATM                                 1.00000
  MAXIMUM NO. ITERATIONS                                   30
  CONVERGENCE TOLERANCE                                     0.000100000

   MASS-YIELD
    SUBSTREAM MIXED   :
    OTHLIQUI   1.00

  INERTS:        WATER      AMMONIA    OTHSOLID

                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                    70.000
  OUTLET PRESSURE       ATM                                  1.0000
  HEAT DUTY             KW                                  -1988.8
  VAPOR FRACTION                                            0.17092E-01


  V-L PHASE EQUILIBRIUM :

     COMP            F(I)           X(I)           Y(I)           K(I)
     WATER          0.94114        0.95315        0.25063        0.26295
     AMMONIA        0.12632E-01    0.70189E-20    0.73907        0.10530E+21
```

```
    OTHLIQUI        0.40287E-01    0.40811E-01    0.10117E-01    0.24789
    OTHSOLID        0.59417E-02    0.60418E-02    0.18568E-03    0.30732E-01

                 ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR WATER                   COOLINGW
 RATE OF CONSUMPTION                   8.2310+06  KG/DAY
 COST                                     1.5178  $/HR

BLOCK:  B1       MODEL: HEATER
------------------------------
  INLET STREAM:          S26
  OUTLET STREAM:         WETBSGH
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                ***  MASS AND ENERGY BALANCE  ***
                             IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           0.106519E+07    0.106519E+07     0.00000
      MASS(KG/DAY  )            516332.         516332.         0.00000
      ENTHALPY(KW      )       -74327.7        -74196.5       -0.176406E-02

                ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    744.889      KG/DAY
   TOTAL CO2E PRODUCTION        744.889      KG/DAY

                    ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE              C                        150.000
  SPECIFIED PRESSURE                 ATM                        1.00000
  MAXIMUM NO. ITERATIONS                                       30
  CONVERGENCE TOLERANCE                                         0.000100000



                     ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                   150.00
  OUTLET PRESSURE       ATM                                 1.0000
  HEAT DUTY             KW                                  131.12
  OUTLET VAPOR FRACTION                                    0.98367



  V-L PHASE EQUILIBRIUM :

     COMP             F(I)           X(I)           Y(I)           K(I)
     WATER          0.98654        0.17619        0.99999         5.6758
     GLUCOSE        0.39372E-05    0.24105E-03    0.15752E-08    0.65348E-05
     XYLOSE         0.21695E-07    0.13196E-05    0.15214E-09    0.11529E-03
     CELLULOS       0.13453E-01    0.82357        0.64962E-05    0.78879E-05
     ENZ/XYL        0.10155E-06    0.62001E-05    0.32607E-09    0.52590E-04
     DIETHER        0.29675E-10    0.85869E-11    0.30025E-10     3.4966

                 ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR STEAM                    MPSTEAM
 RATE OF CONSUMPTION                   5567.5632  KG/DAY
 COST                                     1.0385  $/HR
 CO2 EQUIVALENT EMISSIONS               744.8885  KG/DAY

BLOCK:  B2       MODEL: HEATX
-----------------------------
  HOT SIDE:
```

```
---------
INLET STREAM:             S1
OUTLET STREAM:            STOUT
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
COLD SIDE:
----------
INLET STREAM:             PURE
OUTLET STREAM:            2
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(MOL/HR  )           23558.6         23558.6         0.00000
    MASS(KG/DAY  )           57623.4         57623.4         0.00000
    ENTHALPY(KW      )       -1725.46        -1725.46        0.00000

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***

FLASH SPECS FOR HOT SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                       30
CONVERGENCE TOLERANCE                                         0.000100000

FLASH SPECS FOR COLD SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                       30
CONVERGENCE TOLERANCE                                         0.000100000

FLOW DIRECTION AND SPECIFICATION:
  COUNTERCURRENT   HEAT EXCHANGER
  SPECIFIED HOT OUTLET TEMP
  SPECIFIED VALUE                C                           90.0000
  LMTD CORRECTION FACTOR                                      1.00000

PRESSURE SPECIFICATION:
  HOT  SIDE PRESSURE DROP        ATM                          0.0000
  COLD SIDE PRESSURE DROP        ATM                          0.0000

HEAT TRANSFER COEFFICIENT SPECIFICATION:
  HOT LIQUID    COLD LIQUID      CAL/SEC-SQCM-K               0.0203
  HOT 2-PHASE   COLD LIQUID      CAL/SEC-SQCM-K               0.0203
  HOT VAPOR     COLD LIQUID      CAL/SEC-SQCM-K               0.0203
  HOT LIQUID    COLD 2-PHASE     CAL/SEC-SQCM-K               0.0203
  HOT 2-PHASE   COLD 2-PHASE     CAL/SEC-SQCM-K               0.0203
  HOT VAPOR     COLD 2-PHASE     CAL/SEC-SQCM-K               0.0203
  HOT LIQUID    COLD VAPOR       CAL/SEC-SQCM-K               0.0203
  HOT 2-PHASE   COLD VAPOR       CAL/SEC-SQCM-K               0.0203
  HOT VAPOR     COLD VAPOR       CAL/SEC-SQCM-K               0.0203

                     ***  OVERALL RESULTS  ***

STREAMS:
                --------------------------------------
                |                                    |
S1        ----->|                HOT                 |-----> STOUT
T=  1.4084D+02  |                                    |       T=  9.0000D+01
P=  1.0000D+00  |                                    |       P=  1.0000D+00
V=  1.0000D+00  |                                    |       V=  9.4760D-02
```

```
                   |                                    |
  2        <-----|               COLD                  |<----- PURE
  T=  9.3201D+01  |                                    |       T=  2.2003D+01
  P=  1.0000D+00  |                                    |       P=  1.0000D+00
  V=  0.0000D+00  |                                    |       V=  0.0000D+00
                  -------------------------------------

  DUTY AND AREA:
    CALCULATED HEAT DUTY          KW                          77.0649
    CALCULATED (REQUIRED) AREA    SQM                          1.5847
    ACTUAL EXCHANGER AREA         SQM                          1.5847
    PER CENT OVER-DESIGN                                       0.0000

  HEAT TRANSFER COEFFICIENT:
    AVERAGE COEFFICIENT (DIRTY)   CAL/SEC-SQCM-K               0.0203
    UA (DIRTY)                    CAL/SEC-K                  321.7156

  LOG-MEAN TEMPERATURE DIFFERENCE:
    LMTD CORRECTION FACTOR                                     1.0000
    LMTD (CORRECTED)              C                           57.2140
    NUMBER OF SHELLS IN SERIES                                  1

  PRESSURE DROP:
    HOTSIDE, TOTAL                ATM                          0.0000
    COLDSIDE, TOTAL               ATM                          0.0000

                       ***  ZONE RESULTS  ***

  TEMPERATURE LEAVING EACH ZONE:

                                   HOT
        -------------------------------------------------------------
        |                                                           |
HOT IN  |                          COND                             | HOT OUT
------> |                                                           |------>
 140.8  |                                                           |   90.0
        |                                                           |
COLDOUT |                          LIQ                              | COLDIN
<------ |                                                           |<------
  93.2  |                                                           |   22.0
        |                                                           |
        -------------------------------------------------------------
                                   COLD

  ZONE HEAT TRANSFER AND AREA:

  ZONE       HEAT DUTY       AREA       LMTD       AVERAGE U       UA
             KW              SQM         C         CAL/SEC-SQCM-K  CAL/SEC-K
    1         77.065         1.5847      57.2140     0.0203          321.7156

HEATX COLD-TQCU B2       TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !    93.2006 !     0.0    !
!     3.6698 !     1.0000 !    90.0084 !     0.0    !
!     7.3395 !     1.0000 !    90.0084 !     0.0    !
!    11.0093 !     1.0000 !    86.7982 !     0.0    !
!    14.6790 !     1.0000 !    83.5698 !     0.0    !
!------------+------------+------------+------------!
!    18.3488 !     1.0000 !    80.3229 !     0.0    !
!    22.0185 !     1.0000 !    77.0572 !     0.0    !
!    25.6883 !     1.0000 !    73.7724 !     0.0    !
!    29.3581 !     1.0000 !    70.4682 !     0.0    !
!    33.0278 !     1.0000 !    67.1443 !     0.0    !
!------------+------------+------------+------------!
!    36.6976 !     1.0000 !    63.8004 !     0.0    !
!    40.3673 !     1.0000 !    60.4361 !     0.0    !
!    44.0371 !     1.0000 !    57.0512 !     0.0    !
!    47.7069 !     1.0000 !    53.6454 !     0.0    !
!    51.3766 !     1.0000 !    50.2183 !     0.0    !
!------------+------------+------------+------------!
!    55.0464 !     1.0000 !    46.7697 !     0.0    !
!    58.7161 !     1.0000 !    43.2992 !     0.0    !
!    62.3859 !     1.0000 !    39.8067 !     0.0    !
!    66.0556 !     1.0000 !    36.2918 !     0.0    !
!    69.7254 !     1.0000 !    32.7542 !     0.0    !
!------------+------------+------------+------------!
!    73.3952 !     1.0000 !    29.1937 !     0.0    !
!    77.0649 !     1.0000 !    25.6101 !     0.0    !
-----------------------------------------------------

HEATX HOT-TQCUR B2       TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !   140.8368 !     1.0000 !
!     3.6698 !     1.0000 !   126.1477 !     0.9751 !
!     7.3395 !     1.0000 !    98.7939 !     0.9585 !
!    11.0093 !     1.0000 !   101.3205 !     0.9002 !
!    14.6790 !     1.0000 !   101.2592 !     0.8542 !
!------------+------------+------------+------------!
!    18.3488 !     1.0000 !   101.1909 !     0.8082 !
!    22.0185 !     1.0000 !   101.1142 !     0.7623 !
!    25.6883 !     1.0000 !   101.0276 !     0.7163 !
!    29.3581 !     1.0000 !   100.9289 !     0.6704 !
!    33.0278 !     1.0000 !   100.8154 !     0.6246 !
!------------+------------+------------+------------!
!    36.6976 !     1.0000 !   100.6837 !     0.5787 !
!    40.3673 !     1.0000 !   100.5288 !     0.5329 !
!    44.0371 !     1.0000 !   100.3444 !     0.4872 !
!    47.7069 !     1.0000 !   100.1209 !     0.4416 !
!    51.3766 !     1.0000 !    99.8448 !     0.3961 !
!------------+------------+------------+------------!
!    55.0464 !     1.0000 !    99.4954 !     0.3507 !
!    58.7161 !     1.0000 !    99.0399 !     0.3056 !
!    62.3859 !     1.0000 !    98.4229 !     0.2608 !
!    66.0556 !     1.0000 !    97.5451 !     0.2166 !
!    69.7254 !     1.0000 !    96.2127 !     0.1734 !
!------------+------------+------------+------------!
!    73.3952 !     1.0000 !    94.0115 !     0.1321 !
!    77.0649 !     1.0000 !    90.0000 !  9.4760-02 !
```

```
-----------------------------------------------------

BLOCK:  B3       MODEL: MIXER
-----------------------------
  INLET STREAMS:         STEAM2      STEAM1
  OUTLET STREAM:         S1
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           6683.33         6683.33         0.00000
      MASS(KG/DAY  )           3775.64         3775.64         0.00000
      ENTHALPY(KW      )      -420.616        -420.616       -0.270287E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  B4       MODEL: SEP
---------------------------
  INLET STREAMS:         MEOHIN      S7
  OUTLET STREAMS:        PLAOUT      S8
  PROPERTY OPTION SET:   IDEAL     IDEAL LIQUID / IDEAL GAS

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           86273.5         86273.5        0.168672E-15
      MASS(KG/DAY  )           126829.         126829.        0.137684E-14
      ENTHALPY(KW      )      -4469.96        -4469.36       -0.134255E-03

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            696000.      KG/DAY
   PRODUCT STREAMS CO2E         696000.      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.700929E+32  KG/DAY
   TOTAL CO2E PRODUCTION        0.700929E+32  KG/DAY


                         ***  INPUT DATA  ***

  INLET PRESSURE   ATM                                       1.00000

  FLASH SPECS FOR STREAM S8
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                                0.0
  MAXIMUM NO. ITERATIONS                                  50
  CONVERGENCE TOLERANCE                                    0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= PLAOUT    CPT= PLA       FRACTION=          1.00000


                          ***  RESULTS  ***
```

```
  HEAT DUTY             KW                                 0.12338E+32

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S8         MIXED                1.00000

 COMPONENT = GLUCOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S8         MIXED                1.00000

 COMPONENT = DIETHER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S8         MIXED                1.00000

 COMPONENT = METHANOL
   STREAM     SUBSTREAM    SPLIT FRACTION
   S8         MIXED                1.00000

 COMPONENT = CH2CL2
   STREAM     SUBSTREAM    SPLIT FRACTION
   S8         MIXED                1.00000

 COMPONENT = PLA
   STREAM     SUBSTREAM    SPLIT FRACTION
   PLAOUT     MIXED                1.00000

                     ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR STEAM                     LPSTEAM
 RATE OF CONSUMPTION                    4.8634+32  KG/DAY
 COST                                   8.4392+28  $/HR
 CO2 EQUIVALENT EMISSIONS               7.0093+31  KG/DAY

BLOCK:  B5       MODEL: HEATX
-----------------------------
  HOT SIDE:
  ---------
  INLET STREAM:             S6
  OUTLET STREAM:            S10
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
  COLD SIDE:
  ----------
  INLET STREAM:             S29
  OUTLET STREAM:            S2
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )          0.117605E+07    0.117605E+07     0.00000
      MASS(KG/DAY  )           508517.         508517.         0.00000
      ENTHALPY(KW      )      -88683.7        -88683.7       -0.164088E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***

  FLASH SPECS FOR HOT SIDE:
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000
```

```
FLASH SPECS FOR COLD SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                       30
CONVERGENCE TOLERANCE                                         0.000100000

FLOW DIRECTION AND SPECIFICATION:
  COUNTERCURRENT   HEAT EXCHANGER
  SPECIFIED COLD OUTLET TEMP
  SPECIFIED VALUE              C                             95.0000
  LMTD CORRECTION FACTOR                                      1.00000

PRESSURE SPECIFICATION:
  HOT  SIDE PRESSURE DROP       ATM                           0.0000
  COLD SIDE PRESSURE DROP       ATM                           0.0000

HEAT TRANSFER COEFFICIENT SPECIFICATION:
  HOT LIQUID    COLD LIQUID      CAL/SEC-SQCM-K               0.0203
  HOT 2-PHASE   COLD LIQUID      CAL/SEC-SQCM-K               0.0203
  HOT VAPOR     COLD LIQUID      CAL/SEC-SQCM-K               0.0203
  HOT LIQUID    COLD 2-PHASE     CAL/SEC-SQCM-K               0.0203
  HOT 2-PHASE   COLD 2-PHASE     CAL/SEC-SQCM-K               0.0203
  HOT VAPOR     COLD 2-PHASE     CAL/SEC-SQCM-K               0.0203
  HOT LIQUID    COLD VAPOR       CAL/SEC-SQCM-K               0.0203
  HOT 2-PHASE   COLD VAPOR       CAL/SEC-SQCM-K               0.0203
  HOT VAPOR     COLD VAPOR       CAL/SEC-SQCM-K               0.0203

                     ***  OVERALL RESULTS  ***

STREAMS:
                --------------------------------------
                |                                    |
S6        ----->|               HOT                  |-----> S10
T=  1.4512D+02  |                                    |       T=  1.0246D+02
P=  1.0000D+00  |                                    |       P=  1.0000D+00
V=  1.0000D+00  |                                    |       V=  8.6317D-01
                |                                    |
S2        <-----|               COLD                 |<----- S29
T=  9.5000D+01  |                                    |       T=  5.8831D+01
P=  1.0000D+00  |                                    |       P=  1.0000D+00
V=  0.0000D+00  |                                    |       V=  0.0000D+00
                --------------------------------------

DUTY AND AREA:
  CALCULATED HEAT DUTY          KW                          719.5503
  CALCULATED (REQUIRED) AREA    SQM                          30.9111
  ACTUAL EXCHANGER AREA         SQM                          30.9111
  PER CENT OVER-DESIGN                                        0.0000

HEAT TRANSFER COEFFICIENT:
  AVERAGE COEFFICIENT (DIRTY)   CAL/SEC-SQCM-K                0.0203
  UA (DIRTY)                    CAL/SEC-K                  6275.5314

LOG-MEAN TEMPERATURE DIFFERENCE:
  LMTD CORRECTION FACTOR                                      1.0000
  LMTD (CORRECTED)              C                            27.3860
  NUMBER OF SHELLS IN SERIES                                   1

PRESSURE DROP:
  HOTSIDE, TOTAL                ATM                           0.0000
  COLDSIDE, TOTAL               ATM                           0.0000

                     ***  ZONE RESULTS  ***

TEMPERATURE LEAVING EACH ZONE:
```

```
                                   HOT
        -------------------------------------------------------------
        |                             |                             |
HOT IN  |           VAP               |           COND              | HOT OUT
------> |                             |                             |------>
 145.1  |                        103.1|                             |  102.5
        |                             |                             |
COLDOUT |           LIQ               |           LIQ               | COLDIN
<------ |                             |                             |<------
  95.0  |                         87.9|                             |   58.8
        |                             |                             |
        -------------------------------------------------------------
                                   COLD

  ZONE HEAT TRANSFER AND AREA:

  ZONE       HEAT DUTY       AREA       LMTD       AVERAGE U       UA
             KW              SQM        C          CAL/SEC-SQCM-K  CAL/SEC-K
    1        142.185         5.7160     29.2645     0.0203         1160.4567
    2        577.366        25.1951     26.9598     0.0203         5115.0747

HEATX COLD-TQCU B5       TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0          ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !    95.0000 !     0.0    !
!    34.2643 !     1.0000 !    93.2862 !     0.0    !
!    68.5286 !     1.0000 !    91.5714 !     0.0    !
!   102.7929 !     1.0000 !    89.8554 !     0.0    !
!   137.0572 !     1.0000 !    88.1384 !     0.0    !
!------------+------------+------------+------------!
!   142.1845 !     1.0000 !    87.8814 !     0.0    !
!   171.3215 !     1.0000 !    86.4205 !     0.0    !
!   205.5858 !     1.0000 !    84.7015 !     0.0    !
!   239.8501 !     1.0000 !    82.9817 !     0.0    !
!   274.1144 !     1.0000 !    81.2610 !     0.0    !
!------------+------------+------------+------------!
!   308.3787 !     1.0000 !    79.5395 !     0.0    !
!   342.6430 !     1.0000 !    77.8171 !     0.0    !
!   376.9073 !     1.0000 !    76.0941 !     0.0    !
!   411.1716 !     1.0000 !    74.3703 !     0.0    !
!   445.4359 !     1.0000 !    72.6458 !     0.0    !
!------------+------------+------------+------------!
!   479.7002 !     1.0000 !    70.9208 !     0.0    !
!   513.9645 !     1.0000 !    69.1951 !     0.0    !
!   548.2288 !     1.0000 !    67.4689 !     0.0    !
!   582.4931 !     1.0000 !    65.7422 !     0.0    !
!   616.7574 !     1.0000 !    64.0150 !     0.0    !
!------------+------------+------------+------------!
!   651.0217 !     1.0000 !    62.2874 !     0.0    !
!   685.2860 !     1.0000 !    60.5594 !     0.0    !
!   719.5503 !     1.0000 !    58.8310 !     0.0    !
-----------------------------------------------------

HEATX HOT-TQCUR B5       TQCURV INLET
-------------------------------------
```

```
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !   145.1174 !     1.0000 !
!    34.2643 !     1.0000 !   135.0205 !     1.0000 !
!    68.5286 !     1.0000 !   124.9013 !     1.0000 !
!   102.7929 !     1.0000 !   114.7609 !     1.0000 !
!   137.0572 !     1.0000 !   104.6005 !     1.0000 !
!------------+------------+------------+------------!
!   142.1845 !     1.0000 !   103.0785 ! DEW>1.0000 !
!   171.3215 !     1.0000 !   102.4772 !     0.9936 !
!   205.5858 !     1.0000 !   102.4748 !     0.9854 !
!   239.8501 !     1.0000 !   102.4732 !     0.9773 !
!   274.1144 !     1.0000 !   102.4718 !     0.9691 !
!------------+------------+------------+------------!
!   308.3787 !     1.0000 !   102.4705 !     0.9610 !
!   342.6430 !     1.0000 !   102.4694 !     0.9528 !
!   376.9073 !     1.0000 !   102.4684 !     0.9447 !
!   411.1716 !     1.0000 !   102.4674 !     0.9365 !
!   445.4359 !     1.0000 !   102.4665 !     0.9284 !
!------------+------------+------------+------------!
!   479.7002 !     1.0000 !   102.4657 !     0.9202 !
!   513.9645 !     1.0000 !   102.4649 !     0.9121 !
!   548.2288 !     1.0000 !   102.4641 !     0.9039 !
!   582.4931 !     1.0000 !   102.4634 !     0.8958 !
!   616.7574 !     1.0000 !   102.4628 !     0.8876 !
!------------+------------+------------+------------!
!   651.0217 !     1.0000 !   102.4621 !     0.8795 !
!   685.2860 !     1.0000 !   102.4615 !     0.8713 !
!   719.5503 !     1.0000 !   102.4610 !     0.8632 !
-----------------------------------------------------

BLOCK:  B6       MODEL: MIXER
-----------------------------
  INLET STREAMS:         STEAM3      STEAM5
  OUTLET STREAM:         S6
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           353132.         353132.         0.00000
      MASS(KG/DAY  )           152716.         152716.       -0.762301E-15
      ENTHALPY(KW      )      -23323.9        -23323.9        0.608307E-14

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                        ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                 30
  CONVERGENCE TOLERANCE                                   0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES
```

```
BLOCK:  B7       MODEL: MIXER
-----------------------------
  INLET STREAMS:         ETHOUT1     ETHOUT2
  OUTLET STREAM:         ETHOUTFI
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           10475.5         10475.5         0.00000
      MASS(KG/DAY  )           40407.5         40407.5        0.360129E-15
      ENTHALPY(KW      )       4.55266         4.55266        0.390180E-15

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                        ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                 30
  CONVERGENCE TOLERANCE                                   0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  B8       MODEL: HEATX
-----------------------------
  HOT SIDE:
  ---------
  INLET STREAM:             S10
  OUTLET STREAM:            S15
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
  COLD SIDE:
  ----------
  INLET STREAM:             SA-IN
  OUTLET STREAM:            S11
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           356019.         356019.         0.00000
      MASS(KG/DAY  )           155067.         155067.         0.00000
      ENTHALPY(KW      )      -24365.2        -24365.2       -0.149310E-15

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                        ***  INPUT DATA  ***

  FLASH SPECS FOR HOT SIDE:
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                 30
  CONVERGENCE TOLERANCE                                   0.000100000

  FLASH SPECS FOR COLD SIDE:
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                 30
  CONVERGENCE TOLERANCE                                   0.000100000
```

```
 FLOW DIRECTION AND SPECIFICATION:
   COUNTERCURRENT   HEAT EXCHANGER
   SPECIFIED COLD OUTLET TEMP
   SPECIFIED VALUE                C                        92.0000
   LMTD CORRECTION FACTOR                                   1.00000

 PRESSURE SPECIFICATION:
   HOT  SIDE PRESSURE DROP        ATM                       0.0000
   COLD SIDE PRESSURE DROP        ATM                       0.0000

 HEAT TRANSFER COEFFICIENT SPECIFICATION:
   HOT LIQUID    COLD LIQUID      CAL/SEC-SQCM-K            0.0203
   HOT 2-PHASE   COLD LIQUID      CAL/SEC-SQCM-K            0.0203
   HOT VAPOR     COLD LIQUID      CAL/SEC-SQCM-K            0.0203
   HOT LIQUID    COLD 2-PHASE     CAL/SEC-SQCM-K            0.0203
   HOT 2-PHASE   COLD 2-PHASE     CAL/SEC-SQCM-K            0.0203
   HOT VAPOR     COLD 2-PHASE     CAL/SEC-SQCM-K            0.0203
   HOT LIQUID    COLD VAPOR       CAL/SEC-SQCM-K            0.0203
   HOT 2-PHASE   COLD VAPOR       CAL/SEC-SQCM-K            0.0203
   HOT VAPOR     COLD VAPOR       CAL/SEC-SQCM-K            0.0203

                     ***  OVERALL RESULTS  ***

 STREAMS:
                --------------------------------------
                |                                    |
 S10      ----->|               HOT                  |-----> S15
 T=  1.0246D+02 |                                    |       T=  1.0246D+02
 P=  1.0000D+00 |                                    |       P=  1.0000D+00
 V=  8.6317D-01 |                                    |       V=  8.6175D-01
                |                                    |
 S11      <-----|               COLD                 |<----- SA-IN
 T=  9.2000D+01 |                                    |       T=  2.5000D+01
 P=  1.0000D+00 |                                    |       P=  1.0000D+00
 V=  0.0000D+00 |                                    |       V=  0.0000D+00
                --------------------------------------

 DUTY AND AREA:
   CALCULATED HEAT DUTY           KW                        5.9767
   CALCULATED (REQUIRED) AREA     SQM                       0.2101
   ACTUAL EXCHANGER AREA          SQM                       0.2101
   PER CENT OVER-DESIGN                                     0.0000

 HEAT TRANSFER COEFFICIENT:
   AVERAGE COEFFICIENT (DIRTY)    CAL/SEC-SQCM-K            0.0203
   UA (DIRTY)                     CAL/SEC-K                42.6577

 LOG-MEAN TEMPERATURE DIFFERENCE:
   LMTD CORRECTION FACTOR                                   1.0000
   LMTD (CORRECTED)               C                        33.4645
   NUMBER OF SHELLS IN SERIES                                1

 PRESSURE DROP:
   HOTSIDE, TOTAL                 ATM                       0.0000
   COLDSIDE, TOTAL                ATM                       0.0000

                     ***  ZONE RESULTS  ***

 TEMPERATURE LEAVING EACH ZONE:

                                   HOT
        -------------------------------------------------------------
        |                                                           |
HOT IN  |                          COND                             | HOT OUT
------> |                                                           |------>
 102.5  |                                                           |  102.5
```

```
          |                                                            |
COLDOUT |                          LIQ                               | COLDIN
<------ |                                                            |<------
  92.0  |                                                            |   25.0
        |                                                            |
        --------------------------------------------------------------
                                   COLD

  ZONE HEAT TRANSFER AND AREA:

  ZONE       HEAT DUTY       AREA       LMTD       AVERAGE U       UA
             KW              SQM        C          CAL/SEC-SQCM-K  CAL/SEC-K
    1          5.977         0.2101      33.4645     0.0203          42.6577

HEATX COLD-TQCU B8       TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !    92.0000 !     0.0    !
!     0.2846 !     1.0000 !    88.8173 !     0.0    !
!     0.5692 !     1.0000 !    85.6327 !     0.0    !
!     0.8538 !     1.0000 !    82.4465 !     0.0    !
!     1.1384 !     1.0000 !    79.2589 !     0.0    !
!------------+------------+------------+------------!
!     1.4230 !     1.0000 !    76.0699 !     0.0    !
!     1.7076 !     1.0000 !    72.8798 !     0.0    !
!     1.9922 !     1.0000 !    69.6887 !     0.0    !
!     2.2768 !     1.0000 !    66.4968 !     0.0    !
!     2.5615 !     1.0000 !    63.3042 !     0.0    !
!------------+------------+------------+------------!
!     2.8461 !     1.0000 !    60.1111 !     0.0    !
!     3.1307 !     1.0000 !    56.9176 !     0.0    !
!     3.4153 !     1.0000 !    53.7240 !     0.0    !
!     3.6999 !     1.0000 !    50.5303 !     0.0    !
!     3.9845 !     1.0000 !    47.3368 !     0.0    !
!------------+------------+------------+------------!
!     4.2691 !     1.0000 !    44.1436 !     0.0    !
!     4.5537 !     1.0000 !    40.9509 !     0.0    !
!     4.8383 !     1.0000 !    37.7588 !     0.0    !
!     5.1229 !     1.0000 !    34.5675 !     0.0    !
!     5.4075 !     1.0000 !    31.3772 !     0.0    !
!------------+------------+------------+------------!
!     5.6921 !     1.0000 !    28.1879 !     0.0    !
!     5.9767 !     1.0000 !    25.0000 !     0.0    !
-----------------------------------------------------

HEATX HOT-TQCUR B8       TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
```

```
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !   102.4610 !     0.8632 !
!     0.2846 !     1.0000 !   102.4610 !     0.8631 !
!     0.5692 !     1.0000 !   102.4610 !     0.8630 !
!     0.8538 !     1.0000 !   102.4610 !     0.8630 !
!     1.1384 !     1.0000 !   102.4610 !     0.8629 !
!------------+------------+------------+------------!
!     1.4230 !     1.0000 !   102.4610 !     0.8628 !
!     1.7076 !     1.0000 !   102.4610 !     0.8628 !
!     1.9922 !     1.0000 !   102.4610 !     0.8627 !
!     2.2768 !     1.0000 !   102.4610 !     0.8626 !
!     2.5615 !     1.0000 !   102.4609 !     0.8626 !
!------------+------------+------------+------------!
!     2.8461 !     1.0000 !   102.4609 !     0.8625 !
!     3.1307 !     1.0000 !   102.4609 !     0.8624 !
!     3.4153 !     1.0000 !   102.4609 !     0.8624 !
!     3.6999 !     1.0000 !   102.4609 !     0.8623 !
!     3.9845 !     1.0000 !   102.4609 !     0.8622 !
!------------+------------+------------+------------!
!     4.2691 !     1.0000 !   102.4609 !     0.8622 !
!     4.5537 !     1.0000 !   102.4609 !     0.8621 !
!     4.8383 !     1.0000 !   102.4609 !     0.8620 !
!     5.1229 !     1.0000 !   102.4609 !     0.8620 !
!     5.4075 !     1.0000 !   102.4609 !     0.8619 !
!------------+------------+------------+------------!
!     5.6921 !     1.0000 !   102.4609 !     0.8618 !
!     5.9767 !     1.0000 !   102.4609 !     0.8618 !
-----------------------------------------------------

BLOCK:  B9       MODEL: SEP
---------------------------
  INLET STREAM:          1
  OUTLET STREAMS:        S16         S17
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           824587.         824587.         0.00000
      MASS(KG/DAY  )           368323.         368323.       -0.474103E-15
      ENTHALPY(KW      )      -66579.1        -66579.1       -0.134989E-06

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.510582E-01  KG/DAY
   TOTAL CO2E PRODUCTION        0.510582E-01  KG/DAY


                         ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM S16
  TWO    PHASE  TP  FLASH
  PRESSURE DROP          ATM                                    0.0
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                         0.000100000

  FLASH SPECS FOR STREAM S17
  TWO    PHASE  TP  FLASH
  PRESSURE DROP          ATM                                    0.0
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                         0.000100000
```

```
  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= S16       CPT= WATER     FRACTION=          1.00000
                             GLUCOSE                      1.00000
                             XYLOSE                       1.00000
                             OTHLIQUI                     1.00000
                             LACTICAC                     1.00000
                             DIETHER                      1.00000


                        ***  RESULTS  ***

  HEAT DUTY             KW                                  0.89875E-02

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S16        MIXED                 1.00000

 COMPONENT = GLUCOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S16        MIXED                 1.00000

 COMPONENT = OTHSOLID
   STREAM     SUBSTREAM    SPLIT FRACTION
   S17        MIXED                 1.00000

 COMPONENT = LACTICAC
   STREAM     SUBSTREAM    SPLIT FRACTION
   S16        MIXED                 1.00000

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR STEAM                     LPSTEAM
 RATE OF CONSUMPTION                       0.3543  KG/DAY
 COST                                    6.1474-05  $/HR
 CO2 EQUIVALENT EMISSIONS                5.1058-02  KG/DAY

BLOCK:  B10      MODEL: MIXER
-----------------------------
  INLET STREAMS:         WATER1      HOHIN       S22
  OUTLET STREAM:         S19
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           823001.         823001.         0.00000
      MASS(KG/DAY  )           355871.         355871.       -0.490691E-15
      ENTHALPY(KW      )      -65364.2        -65364.2        0.556570E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
   TOTAL CO2E PRODUCTION         0.00000      KG/DAY

                         ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                         0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  B11      MODEL: HEATX
-----------------------------
```

```
HOT SIDE:
---------
INLET STREAM:             ETHPLA
OUTLET STREAM:            S14
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
COLD SIDE:
----------
INLET STREAM:             S12
OUTLET STREAM:            S13
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT       RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(MOL/HR  )           29105.6         29105.6         0.00000
    MASS(KG/DAY  )           94945.2         94945.2         0.00000
    ENTHALPY(KW      )      -310.976        -310.976         0.00000

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***

FLASH SPECS FOR HOT SIDE:
TWO    PHASE     FLASH
MAXIMUM NO. ITERATIONS                                  30
CONVERGENCE TOLERANCE                                    0.000100000

FLASH SPECS FOR COLD SIDE:
TWO    PHASE     FLASH
MAXIMUM NO. ITERATIONS                                  30
CONVERGENCE TOLERANCE                                    0.000100000

FLOW DIRECTION AND SPECIFICATION:
  COUNTERCURRENT   HEAT EXCHANGER
  SPECIFIED HOT OUTLET TEMP
  SPECIFIED VALUE              C                      180.0000
  LMTD CORRECTION FACTOR                                 1.00000

PRESSURE SPECIFICATION:
  HOT  SIDE PRESSURE DROP        ATM                     0.0000
  COLD SIDE PRESSURE DROP        ATM                     0.0000

HEAT TRANSFER COEFFICIENT SPECIFICATION:
  HOT LIQUID    COLD LIQUID      CAL/SEC-SQCM-K          0.0203
  HOT 2-PHASE   COLD LIQUID      CAL/SEC-SQCM-K          0.0203
  HOT VAPOR     COLD LIQUID      CAL/SEC-SQCM-K          0.0203
  HOT LIQUID    COLD 2-PHASE     CAL/SEC-SQCM-K          0.0203
  HOT 2-PHASE   COLD 2-PHASE     CAL/SEC-SQCM-K          0.0203
  HOT VAPOR     COLD 2-PHASE     CAL/SEC-SQCM-K          0.0203
  HOT LIQUID    COLD VAPOR       CAL/SEC-SQCM-K          0.0203
  HOT 2-PHASE   COLD VAPOR       CAL/SEC-SQCM-K          0.0203
  HOT VAPOR     COLD VAPOR       CAL/SEC-SQCM-K          0.0203

                     ***  OVERALL RESULTS  ***

STREAMS:
                --------------------------------------
                |                                    |
ETHPLA    ----->|                HOT                 |-----> S14
T=  2.8800D+02  |                                    |       T=  1.8000D+02
P=  1.0000D+00  |                                    |       P=  1.0000D+00
```

```
V=  1.0000D+00  |                                    |       V=  3.3964D-01
                |                                    |
S13       <-----|                COLD                |<----- S12
T=  2.3748D+02  |                                    |       T=  1.1000D+02
P=  1.0000D+00  |                                    |       P=  1.0000D+00
V=  8.2084D-01  |                                    |       V=  2.0384D-01
                --------------------------------------

DUTY AND AREA:
  CALCULATED HEAT DUTY           KW                         233.8719
  CALCULATED (REQUIRED) AREA     SQM                          8.6337
  ACTUAL EXCHANGER AREA          SQM                          8.6337
  PER CENT OVER-DESIGN                                        0.0000

HEAT TRANSFER COEFFICIENT:
  AVERAGE COEFFICIENT (DIRTY)    CAL/SEC-SQCM-K               0.0203
  UA (DIRTY)                     CAL/SEC-K                 1752.7959

LOG-MEAN TEMPERATURE DIFFERENCE:
  LMTD CORRECTION FACTOR                                      1.0000
  LMTD (CORRECTED)               C                           31.8687
  NUMBER OF SHELLS IN SERIES                                 1

PRESSURE DROP:
  HOTSIDE, TOTAL                ATM                           0.0000
  COLDSIDE, TOTAL               ATM                           0.0000

                      ***  ZONE RESULTS  ***

TEMPERATURE LEAVING EACH ZONE:

                                  HOT
        -------------------------------------------------------------
        |                             |                             |
HOT IN  |            VAP              |             COND            | HOT OUT
------> |                             |                             |------>
 288.0  |                        242.8|                             |  180.0
        |                             |                             |
COLDOUT |            BOIL             |             BOIL            | COLDIN
<------ |                             |                             |<------
 237.5  |                        230.6|                             |  110.0
        |                             |                             |
        -------------------------------------------------------------
                                  COLD

ZONE HEAT TRANSFER AND AREA:

ZONE       HEAT DUTY       AREA       LMTD       AVERAGE U       UA
           KW             SQM         C          CAL/SEC-SQCM-K  CAL/SEC-K
  1         39.705         1.7315      26.9777     0.0203          351.5239
  2        194.167         6.9022      33.0957     0.0203         1401.2720

HEATX COLD-TQCU B11      TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0          ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
```

| | | | |
|---|---|---|---|
| 0.0 | 1.0000 | 237.4817 | 0.8208 |
| 11.1368 | 1.0000 | 235.8254 | 0.7739 |
| 22.2735 | 1.0000 | 233.9688 | 0.7280 |
| 33.4103 | 1.0000 | 231.8712 | 0.6832 |
| 39.7047 | 1.0000 | 230.5620 | 0.6585 |
| 44.5470 | 1.0000 | 229.4867 | 0.6399 |
| 55.6838 | 1.0000 | 226.7634 | 0.5982 |
| 66.8205 | 1.0000 | 223.6438 | 0.5584 |
| 77.9573 | 1.0000 | 220.0653 | 0.5208 |
| 89.0940 | 1.0000 | 215.9624 | 0.4857 |
| 100.2308 | 1.0000 | 211.2707 | 0.4532 |
| 111.3676 | 1.0000 | 205.9321 | 0.4237 |
| 122.5043 | 1.0000 | 199.9007 | 0.3971 |
| 133.6411 | 1.0000 | 193.1491 | 0.3735 |
| 144.7778 | 1.0000 | 185.6739 | 0.3527 |
| 155.9146 | 1.0000 | 177.4986 | 0.3344 |
| 167.0513 | 1.0000 | 168.6774 | 0.3179 |
| 178.1881 | 1.0000 | 159.2970 | 0.3027 |
| 189.3248 | 1.0000 | 149.4814 | 0.2878 |
| 200.4616 | 1.0000 | 139.3983 | 0.2720 |
| 211.5984 | 1.0000 | 129.2663 | 0.2539 |
| 222.7351 | 1.0000 | 119.3596 | 0.2318 |
| 233.8719 | 1.0000 | 110.0001 | 0.2038 |

HEATX HOT-TQCUR B11      TQCURV INLET

PRESSURE PROFILE:      CONSTANT2
PRESSURE DROP:         0.0         ATM
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

| DUTY KW | PRES ATM | TEMP C | VFRAC |
|---|---|---|---|
| 0.0 | 1.0000 | 288.0000 | 1.0000 |
| 11.1368 | 1.0000 | 275.5733 | 1.0000 |
| 22.2735 | 1.0000 | 262.9532 | 1.0000 |
| 33.4103 | 1.0000 | 250.1239 | 1.0000 |
| 39.7047 | 1.0000 | 242.7737 | DEW>1.0000 |
| 44.5470 | 1.0000 | 242.1041 | 0.9796 |
| 55.6838 | 1.0000 | 240.7216 | 0.9316 |
| 66.8205 | 1.0000 | 239.3530 | 0.8833 |
| 77.9573 | 1.0000 | 237.8944 | 0.8355 |
| 89.0940 | 1.0000 | 236.2918 | 0.7883 |
| 100.2308 | 1.0000 | 234.5027 | 0.7420 |
| 111.3676 | 1.0000 | 232.4854 | 0.6968 |
| 122.5043 | 1.0000 | 230.1950 | 0.6530 |
| 133.6411 | 1.0000 | 227.5815 | 0.6107 |
| 144.7778 | 1.0000 | 224.5889 | 0.5703 |
| 155.9146 | 1.0000 | 221.1562 | 0.5320 |
| 167.0513 | 1.0000 | 217.2186 | 0.4961 |
| 178.1881 | 1.0000 | 212.7109 | 0.4628 |
| 189.3248 | 1.0000 | 207.5728 | 0.4324 |
| 200.4616 | 1.0000 | 201.7541 | 0.4049 |
| 211.5984 | 1.0000 | 195.2219 | 0.3804 |
| 222.7351 | 1.0000 | 187.9652 | 0.3587 |
| 233.8719 | 1.0000 | 180.0000 | 0.3396 |

BLOCK:  B12      MODEL: SEP

INLET STREAM:          3
OUTLET STREAMS:        S27          S28
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

*** MASS AND ENERGY BALANCE ***

| | IN | OUT | RELATIVE DIFF. |
|---|---|---|---|
| TOTAL BALANCE | | | |
| MOLE(MOL/HR ) | 369331. | 369331. | 0.00000 |
| MASS(KG/DAY ) | 175104. | 175104. | 0.00000 |
| ENTHALPY(KW ) | -30418.2 | -30418.2 | 0.235412E-06 |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|---|---|---|
| FEED STREAMS CO2E | 0.00000 | KG/DAY |
| PRODUCT STREAMS CO2E | 0.00000 | KG/DAY |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/DAY |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/DAY |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/DAY |

*** INPUT DATA ***

FLASH SPECS FOR STREAM S27
TWO    PHASE  TP  FLASH
PRESSURE DROP         ATM                                    0.0
MAXIMUM NO. ITERATIONS                                      30
CONVERGENCE TOLERANCE                                        0.000100000

FLASH SPECS FOR STREAM S28
TWO    PHASE  TP  FLASH
PRESSURE DROP         ATM                                    0.0
MAXIMUM NO. ITERATIONS                                      30
CONVERGENCE TOLERANCE                                        0.000100000

FRACTION OF FEED
SUBSTREAM= MIXED
STREAM= S27       CPT= OTHSOLID  FRACTION=          1.00000
                       CELLULOS                     1.00000

*** RESULTS ***

HEAT DUTY             KW                                    -0.71608E-02

COMPONENT = WATER

| STREAM | SUBSTREAM | SPLIT FRACTION |
|---|---|---|
| S28 | MIXED | 1.00000 |

COMPONENT = XYLOSE

| STREAM | SUBSTREAM | SPLIT FRACTION |
|---|---|---|
| S28 | MIXED | 1.00000 |

COMPONENT = OTHLIQUI

| STREAM | SUBSTREAM | SPLIT FRACTION |
|---|---|---|
| S28 | MIXED | 1.00000 |

COMPONENT = OTHSOLID

| STREAM | SUBSTREAM | SPLIT FRACTION |
|---|---|---|
| S27 | MIXED | 1.00000 |

```
 COMPONENT = ENZ/XYL
   STREAM     SUBSTREAM    SPLIT FRACTION
   S28        MIXED                 1.00000

BLOCK:  B13      MODEL: HEATER
------------------------------
  INLET STREAM:          S15
  OUTLET STREAM:         S22
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           353132.         353134.       -0.590438E-05
      MASS(KG/DAY  )           152716.         152717.       -0.590262E-05
      ENTHALPY(KW      )       -24049.5        -27672.5        0.130924

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
   TOTAL CO2E PRODUCTION         0.00000      KG/DAY

                        ***  INPUT DATA  ***
  TWO    PHASE  PV  FLASH
  SPECIFIED PRESSURE                  ATM                       1.00000
  VAPOR FRACTION                                                0.0
  MAXIMUM NO. ITERATIONS                                      30
  CONVERGENCE TOLERANCE                                         0.000100000



                         ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                  102.44
  OUTLET PRESSURE       ATM                                1.0000
  HEAT DUTY             KW                                -3622.0
  OUTLET VAPOR FRACTION                                    0.0000



  V-L PHASE EQUILIBRIUM :

     COMP             F(I)          X(I)          Y(I)          K(I)
     WATER          0.99976       0.99976       0.99991        1.0002
     XYLOSE         0.65407E-07   0.65407E-07   0.15441E-11   0.23608E-04
     OTHSOLID       0.24232E-03   0.24232E-03   0.36884E-04   0.15221
     CELLULOS       0.15774E-08   0.15774E-08   0.16660E-14   0.10561E-05
     ENZ/XYL        0.30621E-06   0.30621E-06   0.87912E-11   0.28710E-04
     DIETHER        0.97728E-10   0.97728E-10   0.54431E-04   0.55697E+06
                      ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR WATER                   COOLINGW
 RATE OF CONSUMPTION                   1.4991+07  KG/DAY
 COST                                     2.7643  $/HR

BLOCK:  B14      MODEL: MIXER
-----------------------------
  INLET STREAM:          ETHIN
  OUTLET STREAM:         ETHIN2
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           9791.78         9791.78         0.00000
      MASS(KG/DAY  )           40000.0         40000.0         0.00000
      ENTHALPY(KW      )       50.2050         50.2050         0.00000

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
   TOTAL CO2E PRODUCTION         0.00000      KG/DAY

                        ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                   30
  CONVERGENCE TOLERANCE                                     0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  B15      MODEL: HEATER
------------------------------
  INLET STREAM:          PLASUGAR
  OUTLET STREAM:         S21
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           820019.         820019.         0.00000
      MASS(KG/DAY  )           368323.         368323.         0.00000
      ENTHALPY(KW      )       -66781.3        -66538.5       -0.363584E-02

                    ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION     1379.39      KG/DAY
   TOTAL CO2E PRODUCTION         1379.39      KG/DAY

                        ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE             C                        37.0000
  SPECIFIED PRESSURE                ATM                       1.00000
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                       0.000100000



                         ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                37.000
  OUTLET PRESSURE       ATM                              1.0000
  HEAT DUTY             KW                               242.81
  OUTLET VAPOR FRACTION                                  0.0000



  V-L PHASE EQUILIBRIUM :

     COMP             F(I)          X(I)          Y(I)          K(I)
     WATER          0.99568       0.99568       1.0000        0.48804E-01
     GLUCOSE        0.43164E-02   0.43164E-02   0.13508E-13   0.15207E-12

                      ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR STEAM                   LPSTEAM
 RATE OF CONSUMPTION                   9570.9890  KG/DAY
 COST                                     1.6608  $/HR
```

```
 CO2 EQUIVALENT EMISSIONS              1379.3933  KG/DAY

BLOCK:  B16      MODEL: HEATER
------------------------------
  INLET STREAM:          S25
  OUTLET STREAM:         S23
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           368101.         368101.         0.00000
      MASS(KG/DAY  )           175104.         175104.         0.00000
      ENTHALPY(KW      )       -30468.0        -30424.4       -0.143057E-02

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E           0.00000      KG/DAY
   PRODUCT STREAMS CO2E        0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000    KG/DAY
   UTILITIES CO2E PRODUCTION   247.618      KG/DAY
   TOTAL CO2E PRODUCTION       247.618      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE               C                        32.0000
  SPECIFIED PRESSURE                  ATM                       1.00000
  MAXIMUM NO. ITERATIONS                                       30
  CONVERGENCE TOLERANCE                                         0.000100000



                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                  32.000
  OUTLET PRESSURE       ATM                                1.0000
  HEAT DUTY             KW                                 43.587
  OUTLET VAPOR FRACTION                                    0.0000



  V-L PHASE EQUILIBRIUM :

     COMP             F(I)          X(I)          Y(I)          K(I)
     WATER           0.82048       0.82048       0.84207       0.36414E-01
     GLUCOSE         0.11625E-04   0.11625E-04   0.11737E-16   0.35821E-13
     XYLOSE          0.10427E-01   0.10427E-01   0.89227E-08   0.30361E-07
     OTHLIQUI        0.16844       0.16844       0.15793       0.33266E-01
     ENZ/XYL         0.64836E-03   0.64836E-03   0.16842E-08   0.92166E-07

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR STEAM                   LPSTEAM
 RATE OF CONSUMPTION                 1718.1100  KG/DAY
 COST                                   0.2981  $/HR
 CO2 EQUIVALENT EMISSIONS             247.6180  KG/DAY

BLOCK:  B17      MODEL: HEATER
------------------------------
  INLET STREAM:          S13
  OUTLET STREAM:         S24
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           14557.0         14557.0         0.00000
      MASS(KG/DAY  )           52808.1         52808.1         0.00000
      ENTHALPY(KW      )       -79.4113        1.45976        -1.01838

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E           0.00000      KG/DAY
   PRODUCT STREAMS CO2E        0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000    KG/DAY
   UTILITIES CO2E PRODUCTION   673.492      KG/DAY
   TOTAL CO2E PRODUCTION       673.492      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE               C                       288.000
  SPECIFIED PRESSURE                  ATM                       1.00000
  MAXIMUM NO. ITERATIONS                                      100
  CONVERGENCE TOLERANCE                                         0.00100000



                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                 288.00
  OUTLET PRESSURE       ATM                                1.0000
  HEAT DUTY             KW                                 80.893
  OUTLET VAPOR FRACTION                                    0.99943



  V-L PHASE EQUILIBRIUM :

     COMP             F(I)          X(I)          Y(I)          K(I)
     WATER           0.32541       0.53131E-02   0.32559        61.281
     GLUCOSE         0.22104E-02   0.22407E-02   0.22104E-02   0.98650
     DIETHER         0.67199       0.32085       0.67220        2.0951
     PLA             0.38492E-03   0.67160       0.29359E-24   0.43715E-24

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                 ELEC
 RATE OF CONSUMPTION                     80.8934  KW
 COST                                     6.2692  $/HR
 CO2 EQUIVALENT EMISSIONS               673.4923  KG/DAY

BLOCK:  B18      MODEL: DSTWU
-----------------------------
  INLET STREAM:          S8
  CONDENSER OUTLET:      X2
  REBOILER OUTLET:       X1
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           86267.9         86267.9         0.00000
      MASS(KG/DAY  )           116169.         116169.        -0.137792E-14
      ENTHALPY(KW      )       -4469.36        -4443.62       -0.575965E-02

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E           696000.      KG/DAY
   PRODUCT STREAMS CO2E        696000.      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000    KG/DAY
   UTILITIES CO2E PRODUCTION   0.00000      KG/DAY
   TOTAL CO2E PRODUCTION       0.00000      KG/DAY

                       ***  INPUT DATA  ***
   HEAVY KEY COMPONENT                                          METHANOL
   RECOVERY FOR HEAVY KEY                                    0.00100000
   LIGHT KEY COMPONENT                                            CH2CL2
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  RECOVERY FOR LIGHT KEY                                    0.58580
  TOP STAGE PRESSURE (ATM     )                             1.00000
  BOTTOM STAGE PRESSURE (ATM     )                          1.00000
  NO. OF EQUILIBRIUM STAGES                                10.0000
  DISTILLATE VAPOR FRACTION                                 0.0

                       ***  RESULTS  ***
  DISTILLATE TEMP.  (C       )                             40.1463
  BOTTOM TEMP.  (C       )                                 55.1613
  MINIMUM REFLUX RATIO                                      1.21895
  ACTUAL REFLUX RATIO                                       5.88645
  MINIMUM STAGES                                            8.46443
  ACTUAL EQUILIBRIUM STAGES                                10.0000
  NUMBER OF ACTUAL STAGES ABOVE FEED                        9.03958
  DIST. VS FEED                                             0.26705
  CONDENSER COOLING REQUIRED (KW      )                 1,239.61
  NET CONDENSER DUTY (KW      )                        -1,239.61
  REBOILER HEATING REQUIRED (KW      )                  1,265.35
  NET REBOILER DUTY (KW      )                          1,265.35

BLOCK:  B19      MODEL: HEATX
-----------------------------
 HOT SIDE:
 ---------
 INLET STREAM:             PLA1
 OUTLET STREAM:            S4
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
 COLD SIDE:
 ----------
 INLET STREAM:             STEAM4
 OUTLET STREAM:            STEAM5
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
  TOTAL BALANCE
     MOLE(MOL/HR  )           304235.         304235.         0.00000
     MASS(KG/DAY  )           224573.         224573.        0.259192E-15
     ENTHALPY(KW      )      -18773.2        -18773.2       -0.193786E-15

                   ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E          0.00000      KG/DAY
  PRODUCT STREAMS CO2E       0.00000      KG/DAY
  NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
  UTILITIES CO2E PRODUCTION  0.00000      KG/DAY
  TOTAL CO2E PRODUCTION      0.00000      KG/DAY

                       ***  INPUT DATA  ***

 FLASH SPECS FOR HOT SIDE:
 TWO    PHASE      FLASH
 MAXIMUM NO. ITERATIONS                                  30
 CONVERGENCE TOLERANCE                                    0.000100000

 FLASH SPECS FOR COLD SIDE:
 TWO    PHASE      FLASH
 MAXIMUM NO. ITERATIONS                                  30
 CONVERGENCE TOLERANCE                                    0.000100000

 FLOW DIRECTION AND SPECIFICATION:
   COUNTERCURRENT   HEAT EXCHANGER
   SPECIFIED HOT OUTLET TEMP
   SPECIFIED VALUE              C                      110.0000
   LMTD CORRECTION FACTOR                                 1.00000

 PRESSURE SPECIFICATION:
```

```
   HOT  SIDE PRESSURE DROP        ATM                         0.0000
   COLD SIDE PRESSURE DROP        ATM                         0.0000

 HEAT TRANSFER COEFFICIENT SPECIFICATION:
   HOT LIQUID    COLD LIQUID      CAL/SEC-SQCM-K              0.0203
   HOT 2-PHASE   COLD LIQUID      CAL/SEC-SQCM-K              0.0203
   HOT VAPOR     COLD LIQUID      CAL/SEC-SQCM-K              0.0203
   HOT LIQUID    COLD 2-PHASE     CAL/SEC-SQCM-K              0.0203
   HOT 2-PHASE   COLD 2-PHASE     CAL/SEC-SQCM-K              0.0203
   HOT VAPOR     COLD 2-PHASE     CAL/SEC-SQCM-K              0.0203
   HOT LIQUID    COLD VAPOR       CAL/SEC-SQCM-K              0.0203
   HOT 2-PHASE   COLD VAPOR       CAL/SEC-SQCM-K              0.0203
   HOT VAPOR     COLD VAPOR       CAL/SEC-SQCM-K              0.0203

                       ***  OVERALL RESULTS  ***

 STREAMS:
                 --------------------------------------
                 |                                    |
 PLA1      ----->|               HOT                  |-----> S4
 T=  1.7000D+02  |                                    |       T=  1.1000D+02
 P=  1.0000D+00  |                                    |       P=  1.0000D+00
 V=  3.2022D-01  |                                    |       V=  2.0383D-01
                 |                                    |
 STEAM5    <-----|               COLD                 |<----- STEAM4
 T=  1.5520D+02  |                                    |       T=  1.0330D+02
 P=  1.0000D+00  |                                    |       P=  1.0000D+00
 V=  1.0000D+00  |                                    |       V=  1.0000D+00
                 --------------------------------------

 DUTY AND AREA:
   CALCULATED HEAT DUTY           KW                        136.8932
   CALCULATED (REQUIRED) AREA     SQM                        15.7617
   ACTUAL EXCHANGER AREA          SQM                        15.7617
   PER CENT OVER-DESIGN                                       0.0000

 HEAT TRANSFER COEFFICIENT:
   AVERAGE COEFFICIENT (DIRTY)    CAL/SEC-SQCM-K              0.0203
   UA (DIRTY)                     CAL/SEC-K                3199.9323

 LOG-MEAN TEMPERATURE DIFFERENCE:
   LMTD CORRECTION FACTOR                                     1.0000
   LMTD (CORRECTED)               C                          10.2178
   NUMBER OF SHELLS IN SERIES                                   1

 PRESSURE DROP:
   HOTSIDE, TOTAL                 ATM                         0.0000
   COLDSIDE, TOTAL                ATM                         0.0000

                       ***  ZONE RESULTS  ***

 TEMPERATURE LEAVING EACH ZONE:

                                   HOT
       -------------------------------------------------------------
       |                                                           |
HOT IN |                          COND                             | HOT OUT
------>|                                                           |------>
 170.0 |                                                           |  110.0
       |                                                           |
COLDOUT|                          VAP                              | COLDIN
<------|                                                           |<------
 155.2 |                                                           |  103.3
       |                                                           |
       -------------------------------------------------------------
                                  COLD
```

ZONE HEAT TRANSFER AND AREA:

| ZONE | HEAT DUTY | AREA | LMTD | AVERAGE U | UA |
|---|---|---|---|---|---|
| | KW | SQM | C | CAL/SEC-SQCM-K | CAL/SEC-K |
| 1 | 136.893 | 15.7617 | 10.2178 | 0.0203 | 3199.9323 |

HEATX COLD-TQCU B19      TQCURV INLET
------------------------------------

PRESSURE PROFILE:      CONSTANT2
PRESSURE DROP:         0.0         ATM
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

| DUTY KW | PRES ATM | TEMP C | VFRAC |
|---|---|---|---|
| 0.0 | 1.0000 | 155.2010 | 1.0000 |
| 6.5187 | 1.0000 | 152.7431 | 1.0000 |
| 13.0374 | 1.0000 | 150.2837 | 1.0000 |
| 19.5562 | 1.0000 | 147.8230 | 1.0000 |
| 26.0749 | 1.0000 | 145.3608 | 1.0000 |
| 32.5936 | 1.0000 | 142.8973 | 1.0000 |
| 39.1123 | 1.0000 | 140.4323 | 1.0000 |
| 45.6311 | 1.0000 | 137.9660 | 1.0000 |
| 52.1498 | 1.0000 | 135.4984 | 1.0000 |
| 58.6685 | 1.0000 | 133.0294 | 1.0000 |
| 65.1872 | 1.0000 | 130.5591 | 1.0000 |
| 71.7060 | 1.0000 | 128.0875 | 1.0000 |
| 78.2247 | 1.0000 | 125.6146 | 1.0000 |
| 84.7434 | 1.0000 | 123.1404 | 1.0000 |
| 91.2621 | 1.0000 | 120.6650 | 1.0000 |
| 97.7809 | 1.0000 | 118.1883 | 1.0000 |
| 104.2996 | 1.0000 | 115.7105 | 1.0000 |
| 110.8183 | 1.0000 | 113.2314 | 1.0000 |
| 117.3370 | 1.0000 | 110.7512 | 1.0000 |
| 123.8558 | 1.0000 | 108.2698 | 1.0000 |
| 130.3745 | 1.0000 | 105.7872 | 1.0000 |
| 136.8932 | 1.0000 | 103.3036 | 1.0000 |

HEATX HOT-TQCUR B19      TQCURV INLET
------------------------------------

PRESSURE PROFILE:      CONSTANT2
PRESSURE DROP:         0.0         ATM
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

| DUTY KW | PRES ATM | TEMP C | VFRAC |
|---|---|---|---|
| 0.0 | 1.0000 | 170.0000 | 0.3202 |
| 6.5187 | 1.0000 | 167.3315 | 0.3156 |
| 13.0374 | 1.0000 | 164.6162 | 0.3111 |
| 19.5562 | 1.0000 | 161.8571 | 0.3067 |
| 26.0749 | 1.0000 | 159.0572 | 0.3023 |
| 32.5936 | 1.0000 | 156.2201 | 0.2980 |
| 39.1123 | 1.0000 | 153.3495 | 0.2936 |
| 45.6311 | 1.0000 | 150.4497 | 0.2892 |
| 52.1498 | 1.0000 | 147.5250 | 0.2848 |
| 58.6685 | 1.0000 | 144.5803 | 0.2802 |
| 65.1872 | 1.0000 | 141.6209 | 0.2756 |
| 71.7060 | 1.0000 | 138.6525 | 0.2707 |
| 78.2247 | 1.0000 | 135.6810 | 0.2657 |
| 84.7434 | 1.0000 | 132.7131 | 0.2604 |
| 91.2621 | 1.0000 | 129.7555 | 0.2548 |
| 97.7809 | 1.0000 | 126.8156 | 0.2489 |
| 104.2996 | 1.0000 | 123.9012 | 0.2426 |
| 110.8183 | 1.0000 | 121.0202 | 0.2359 |
| 117.3370 | 1.0000 | 118.1811 | 0.2287 |
| 123.8558 | 1.0000 | 115.3923 | 0.2210 |
| 130.3745 | 1.0000 | 112.6624 | 0.2127 |
| 136.8932 | 1.0000 | 110.0000 | 0.2038 |

BLOCK:  B20      MODEL: HEATX
----------------------------

HOT SIDE:
---------
INLET STREAM:             PROD-H
OUTLET STREAM:            PROD-C
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
COLD SIDE:
----------
INLET STREAM:             WETBSGC
OUTLET STREAM:            S26
PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

*** MASS AND ENERGY BALANCE ***

| | IN | OUT | RELATIVE DIFF. |
|---|---|---|---|
| TOTAL BALANCE | | | |
| MOLE(MOL/HR ) | 0.219285E+07 | 0.219285E+07 | 0.00000 |
| MASS(KG/DAY ) | 0.103501E+07 | 0.103501E+07 | 0.00000 |
| ENTHALPY(KW ) | -164098. | -164098. | 0.00000 |

*** CO2 EQUIVALENT SUMMARY ***

| | | |
|---|---|---|
| FEED STREAMS CO2E | 0.00000 | KG/DAY |
| PRODUCT STREAMS CO2E | 0.00000 | KG/DAY |
| NET STREAMS CO2E PRODUCTION | 0.00000 | KG/DAY |
| UTILITIES CO2E PRODUCTION | 0.00000 | KG/DAY |
| TOTAL CO2E PRODUCTION | 0.00000 | KG/DAY |

*** INPUT DATA ***

FLASH SPECS FOR HOT SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                   30
CONVERGENCE TOLERANCE                                    0.000100000

FLASH SPECS FOR COLD SIDE:
TWO    PHASE      FLASH
MAXIMUM NO. ITERATIONS                                   30
CONVERGENCE TOLERANCE                                    0.000100000

FLOW DIRECTION AND SPECIFICATION:
COUNTERCURRENT   HEAT EXCHANGER

```
   SPECIFIED COLD APPROACH TEMP
   SPECIFIED VALUE              C                       10.0000
   TEMPERATURE TOLERANCE        C                        0.01000
   LMTD CORRECTION FACTOR                                1.00000

 PRESSURE SPECIFICATION:
   HOT  SIDE PRESSURE DROP      ATM                      0.0000
   COLD SIDE PRESSURE DROP      ATM                      0.0000

 HEAT TRANSFER COEFFICIENT SPECIFICATION:
   HOT LIQUID    COLD LIQUID    CAL/SEC-SQCM-K           0.0203
   HOT 2-PHASE   COLD LIQUID    CAL/SEC-SQCM-K           0.0203
   HOT VAPOR     COLD LIQUID    CAL/SEC-SQCM-K           0.0203
   HOT LIQUID    COLD 2-PHASE   CAL/SEC-SQCM-K           0.0203
   HOT 2-PHASE   COLD 2-PHASE   CAL/SEC-SQCM-K           0.0203
   HOT VAPOR     COLD 2-PHASE   CAL/SEC-SQCM-K           0.0203
   HOT LIQUID    COLD VAPOR     CAL/SEC-SQCM-K           0.0203
   HOT 2-PHASE   COLD VAPOR     CAL/SEC-SQCM-K           0.0203
   HOT VAPOR     COLD VAPOR     CAL/SEC-SQCM-K           0.0203

                    ***  OVERALL RESULTS  ***

 STREAMS:
                ------------------------------------
                |                                  |
 PROD-H    ----->|               HOT                |-----> PROD-C
 T=  1.5000D+02 |                                  |       T=  1.0278D+02
 P=  1.0000D+00 |                                  |       P=  1.0000D+00
 V=  9.9170D-01 |                                  |       V=  2.1796D-02
                |                                  |
 S26      <-----|               COLD               |<----- WETBSGC
 T=  1.4000D+02 |                                  |       T=  7.5901D+01
 P=  1.0000D+00 |                                  |       P=  1.0000D+00
 V=  9.8256D-01 |                                  |       V=  0.0000D+00
                ------------------------------------

 DUTY AND AREA:
   CALCULATED HEAT DUTY         KW                   13538.1730
   CALCULATED (REQUIRED) AREA   SQM                   4839.9234
   ACTUAL EXCHANGER AREA        SQM                   4839.9234
   PER CENT OVER-DESIGN                                  0.0000

 HEAT TRANSFER COEFFICIENT:
   AVERAGE COEFFICIENT (DIRTY)    CAL/SEC-SQCM-K         0.0203
   UA (DIRTY)                   CAL/SEC-K           982596.4649

 LOG-MEAN TEMPERATURE DIFFERENCE:
   LMTD CORRECTION FACTOR                                1.0000
   LMTD (CORRECTED)             C                        3.2908
   NUMBER OF SHELLS IN SERIES                             1

 PRESSURE DROP:
   HOTSIDE, TOTAL               ATM                      0.0000
   COLDSIDE, TOTAL              ATM                      0.0000

                    ***  ZONE RESULTS  ***

 TEMPERATURE LEAVING EACH ZONE:

                                 HOT
       ------------------------------------------------------------
       |                             |                             |
HOT IN |            COND             |            COND             | HOT OUT
------>|                             |                             |------>
 150.0 |                        102.8|                             |  102.8
       |                             |                             |
```

```
COLDOUT |            BOIL             |             LIQ             | COLDIN
<------ |                             |                             |<------
 140.0  |                        102.7|                             |   75.9
        |                             |                             |
        ------------------------------------------------------------
                                  COLD

  ZONE HEAT TRANSFER AND AREA:

  ZONE      HEAT DUTY      AREA       LMTD      AVERAGE U       UA
              KW           SQM         C       CAL/SEC-SQCM-K  CAL/SEC-K
    1      12810.020     4711.4352     3.1987     0.0203      956510.9255
    2        728.153      128.4882     6.6672     0.0203       26085.5394

HEATX COLD-TQCU B20      TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !   140.0000 !     0.9826 !
!   644.6749 !     1.0000 !   107.5379 !     0.9604 !
!  1289.3498 !     1.0000 !   103.6307 !     0.9114 !
!  1934.0247 !     1.0000 !   103.2498 !     0.8599 !
!  2578.6996 !     1.0000 !   103.1507 !     0.8085 !
!------------+------------+------------+------------!
!  3223.3745 !     1.0000 !   103.0937 !     0.7573 !
!  3868.0494 !     1.0000 !   103.0476 !     0.7062 !
!  4512.7243 !     1.0000 !   103.0069 !     0.6551 !
!  5157.3992 !     1.0000 !   102.9704 !     0.6041 !
!  5802.0741 !     1.0000 !   102.9376 !     0.5532 !
!------------+------------+------------+------------!
!  6446.7490 !     1.0000 !   102.9082 !     0.5023 !
!  7091.4239 !     1.0000 !   102.8816 !     0.4513 !
!  7736.0988 !     1.0000 !   102.8577 !     0.4004 !
!  8380.7738 !     1.0000 !   102.8360 !     0.3495 !
!  9025.4487 !     1.0000 !   102.8163 !     0.2986 !
!------------+------------+------------+------------!
!  9670.1236 !     1.0000 !   102.7984 !     0.2478 !
!  1.0315+04 !     1.0000 !   102.7821 !     0.1969 !
!  1.0959+04 !     1.0000 !   102.7671 !     0.1460 !
!  1.1604+04 !     1.0000 !   102.7533 !  9.5142-02 !
!  1.2249+04 !     1.0000 !   102.7406 !  4.4277-02 !
!------------+------------+------------+------------!
!  1.2810+04 !     1.0000 !   102.7302 ! BUB>0.0    !
!  1.2893+04 !     1.0000 !    99.6689 !     0.0    !
!  1.3538+04 !     1.0000 !    75.9008 !     0.0    !
-----------------------------------------------------

HEATX HOT-TQCUR B20      TQCURV INLET
-------------------------------------
  PRESSURE PROFILE:      CONSTANT2
  PRESSURE DROP:         0.0         ATM
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
!  DUTY      !  PRES      !  TEMP      !  VFRAC     !
!            !            !            !            !
```

```
!            !            !            !            !
!            !            !            !            !
!  KW        !  ATM       !  C         !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !  150.0000  !     0.9917 !
!   644.6749 !     1.0000 !  108.2917  !     0.9788 !
!  1289.3498 !     1.0000 !  104.1842  !     0.9332 !
!  1934.0247 !     1.0000 !  103.7788  !     0.8852 !
!  2578.6996 !     1.0000 !  103.5626  !     0.8372 !
!------------+------------+------------+------------!
!  3223.3745 !     1.0000 !  103.4115  !     0.7893 !
!  3868.0494 !     1.0000 !  103.2982  !     0.7413 !
!  4512.7243 !     1.0000 !  103.2097  !     0.6934 !
!  5157.3992 !     1.0000 !  103.1388  !     0.6454 !
!  5802.0741 !     1.0000 !  103.0806  !     0.5975 !
!------------+------------+------------+------------!
!  6446.7490 !     1.0000 !  103.0321  !     0.5495 !
!  7091.4239 !     1.0000 !  102.9910  !     0.5016 !
!  7736.0988 !     1.0000 !  102.9558  !     0.4536 !
!  8380.7738 !     1.0000 !  102.9252  !     0.4056 !
!  9025.4487 !     1.0000 !  102.8985  !     0.3576 !
!------------+------------+------------+------------!
!  9670.1236 !     1.0000 !  102.8749  !     0.3097 !
!  1.0315+04 !     1.0000 !  102.8539  !     0.2617 !
!  1.0959+04 !     1.0000 !  102.8351  !     0.2137 !
!  1.1604+04 !     1.0000 !  102.8182  !     0.1657 !
!  1.2249+04 !     1.0000 !  102.8028  !     0.1178 !
!------------+------------+------------+------------!
!  1.2810+04 !     1.0000 !  102.7907  !  7.5991-02 !
!  1.2893+04 !     1.0000 !  102.7889  !  6.9778-02 !
!  1.3538+04 !     1.0000 !  102.7762  !  2.1796-02 !
-----------------------------------------------------

BLOCK:  B21      MODEL: SEP
---------------------------
  INLET STREAM:          S19
  OUTLET STREAMS:        S29         S30
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )            823001.         823001.         0.00000
      MASS(KG/DAY  )            355871.         355871.        0.163564E-15
      ENTHALPY(KW      )       -65364.2        -65364.2       -0.107330E-08

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
   TOTAL CO2E PRODUCTION         0.00000      KG/DAY


                       ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM S29
  TWO    PHASE  TP  FLASH
  PRESSURE DROP        ATM                                 0.0
  MAXIMUM NO. ITERATIONS                                 30
  CONVERGENCE TOLERANCE                                    0.000100000

  FLASH SPECS FOR STREAM S30
  TWO    PHASE  TP  FLASH
  PRESSURE DROP        ATM                                 0.0
  MAXIMUM NO. ITERATIONS                                 30
  CONVERGENCE TOLERANCE                                    0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= S30       CPT= WATER     FRACTION=          0.0
                             GLUCOSE                      0.0
                             XYLOSE                       0.0
                             AMMONIA                      0.0
                             OTHLIQUI                     1.00000
                             H2SO4                        0.0
                             CAOH2                        0.0
                             CASO4                        0.0
                             OTHSOLID                     1.00000
                             CELLULOS                     0.0
                             ENZ/XYL                      0.0
                             NACIT                        0.0
                             LACTICAC                     0.0
                             DIETHER                      0.0
                             N2                           0.0
                             METHANOL                     0.0
                             CH2CL2                       0.0
                             ETHYL-01                     0.0
                             PLA                          0.0


                        ***  RESULTS  ***

  HEAT DUTY             KW                                 0.70155E-04

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S29        MIXED                 1.00000

 COMPONENT = GLUCOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S29        MIXED                 1.00000

 COMPONENT = XYLOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S29        MIXED                 1.00000

 COMPONENT = OTHSOLID
   STREAM     SUBSTREAM    SPLIT FRACTION
   S30        MIXED                 1.00000

 COMPONENT = CELLULOS
   STREAM     SUBSTREAM    SPLIT FRACTION
   S29        MIXED                 1.00000

 COMPONENT = ENZ/XYL
   STREAM     SUBSTREAM    SPLIT FRACTION
   S29        MIXED                 1.00000

 COMPONENT = DIETHER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S29        MIXED                 1.00000

BLOCK:  B22      MODEL: MIXER
-----------------------------
  INLET STREAMS:         XYLSUGAR    RECYCLE
  OUTLET STREAM:         S25
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
```

```
 TOTAL BALANCE
    MOLE(MOL/HR  )           368101.        368101.         0.00000
    MASS(KG/DAY  )           175104.        175104.         0.00000
    ENTHALPY(KW      )      -30468.0       -30468.0         0.00000

                 ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                     ***  INPUT DATA  ***
TWO    PHASE     FLASH
MAXIMUM NO. ITERATIONS                                 30
CONVERGENCE TOLERANCE                                   0.000100000
OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  B23      MODEL: HEATX
-----------------------------
  HOT SIDE:
  ---------
  INLET STREAM:             5
  OUTLET STREAM:            S34
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE
  COLD SIDE:
  ----------
  INLET STREAM:             8
  OUTLET STREAM:            S36
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                 ***  MASS AND ENERGY BALANCE  ***
                              IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(MOL/HR  )           53054.4        53054.4         0.00000
    MASS(KG/DAY  )           37818.3        37818.3       -0.192393E-15
    ENTHALPY(KW      )      -5157.08       -5157.08         0.00000

                 ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                     ***  INPUT DATA  ***

  FLASH SPECS FOR HOT SIDE:
  TWO    PHASE     FLASH
  MAXIMUM NO. ITERATIONS                               30
  CONVERGENCE TOLERANCE                                 0.000100000

  FLASH SPECS FOR COLD SIDE:
  TWO    PHASE     FLASH
  MAXIMUM NO. ITERATIONS                               30
  CONVERGENCE TOLERANCE                                 0.000100000

  FLOW DIRECTION AND SPECIFICATION:
    COUNTERCURRENT   HEAT EXCHANGER
    SPECIFIED COLD OUTLET TEMP
    SPECIFIED VALUE              C                     95.0000
    LMTD CORRECTION FACTOR                              1.00000

  PRESSURE SPECIFICATION:
    HOT  SIDE PRESSURE DROP        ATM                  0.0000
    COLD SIDE PRESSURE DROP        ATM                  0.0000
```

```
  HEAT TRANSFER COEFFICIENT SPECIFICATION:
    HOT LIQUID    COLD LIQUID      CAL/SEC-SQCM-K          0.0203
    HOT 2-PHASE   COLD LIQUID      CAL/SEC-SQCM-K          0.0203
    HOT VAPOR     COLD LIQUID      CAL/SEC-SQCM-K          0.0203
    HOT LIQUID    COLD 2-PHASE     CAL/SEC-SQCM-K          0.0203
    HOT 2-PHASE   COLD 2-PHASE     CAL/SEC-SQCM-K          0.0203
    HOT VAPOR     COLD 2-PHASE     CAL/SEC-SQCM-K          0.0203
    HOT LIQUID    COLD VAPOR       CAL/SEC-SQCM-K          0.0203
    HOT 2-PHASE   COLD VAPOR       CAL/SEC-SQCM-K          0.0203
    HOT VAPOR     COLD VAPOR       CAL/SEC-SQCM-K          0.0203

                     ***  OVERALL RESULTS  ***

  STREAMS:
                --------------------------------------
                |                                    |
  5       ----->|               HOT                  |-----> S34
  T=  1.0330D+02|                                    |       T=  4.5919D+01
  P=  1.0000D+00|                                    |       P=  1.0000D+00
  V=  0.0000D+00|                                    |       V=  0.0000D+00
                |                                    |
  S36     <-----|               COLD                 |<----- 8
  T=  9.5000D+01|                                    |       T=  5.0000D+00
  P=  1.0000D+00|                                    |       P=  1.0000D+00
  V=  0.0000D+00|                                    |       V=  0.0000D+00
                --------------------------------------

  DUTY AND AREA:
    CALCULATED HEAT DUTY          KW                      53.0440
    CALCULATED (REQUIRED) AREA    SQM                      3.0516
    ACTUAL EXCHANGER AREA         SQM                      3.0516
    PER CENT OVER-DESIGN                                   0.0000

  HEAT TRANSFER COEFFICIENT:
    AVERAGE COEFFICIENT (DIRTY)   CAL/SEC-SQCM-K           0.0203
    UA (DIRTY)                    CAL/SEC-K              619.5430

  LOG-MEAN TEMPERATURE DIFFERENCE:
    LMTD CORRECTION FACTOR                                 1.0000
    LMTD (CORRECTED)              C                       20.4495
    NUMBER OF SHELLS IN SERIES                              1

  PRESSURE DROP:
    HOTSIDE, TOTAL                ATM                      0.0000
    COLDSIDE, TOTAL               ATM                      0.0000

                     ***  ZONE RESULTS  ***

  TEMPERATURE LEAVING EACH ZONE:

                                  HOT
        -------------------------------------------------------------
        |                                                           |
HOT IN  |                         LIQ                               | HOT OUT
------> |                                                           |------>
 103.3  |                                                           |   45.9
        |                                                           |
COLDOUT |                         LIQ                               | COLDIN
<------ |                                                           |<------
  95.0  |                                                           |    5.0
        |                                                           |
        -------------------------------------------------------------
                                  COLD

  ZONE HEAT TRANSFER AND AREA:
```

```
 ZONE       HEAT DUTY       AREA       LMTD       AVERAGE U       UA
            KW              SQM        C          CAL/SEC-SQCM-K  CAL/SEC-K
   1         53.044         3.0516      20.4495     0.0203         619.5430

HEATX COLD-TQCU B23      TQCURV INLET
-------------------------------------
 PRESSURE PROFILE:      CONSTANT2
 PRESSURE DROP:         0.0         ATM
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
! DUTY       ! PRES       ! TEMP       ! VFRAC      !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
! KW         ! ATM        ! C          !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !    95.0000 !     0.0    !
!     2.5259 !     1.0000 !    90.7587 !     0.0    !
!     5.0518 !     1.0000 !    86.5096 !     0.0    !
!     7.5777 !     1.0000 !    82.2532 !     0.0    !
!    10.1036 !     1.0000 !    77.9900 !     0.0    !
!------------+------------+------------+------------!
!    12.6295 !     1.0000 !    73.7206 !     0.0    !
!    15.1554 !     1.0000 !    69.4454 !     0.0    !
!    17.6813 !     1.0000 !    65.1650 !     0.0    !
!    20.2072 !     1.0000 !    60.8800 !     0.0    !
!    22.7331 !     1.0000 !    56.5908 !     0.0    !
!------------+------------+------------+------------!
!    25.2590 !     1.0000 !    52.2980 !     0.0    !
!    27.7849 !     1.0000 !    48.0022 !     0.0    !
!    30.3108 !     1.0000 !    43.7038 !     0.0    !
!    32.8367 !     1.0000 !    39.4036 !     0.0    !
!    35.3626 !     1.0000 !    35.1019 !     0.0    !
!------------+------------+------------+------------!
!    37.8886 !     1.0000 !    30.7995 !     0.0    !
!    40.4145 !     1.0000 !    26.4968 !     0.0    !
!    42.9404 !     1.0000 !    22.1944 !     0.0    !
!    45.4663 !     1.0000 !    17.8930 !     0.0    !
!    47.9922 !     1.0000 !    13.5932 !     0.0    !
!------------+------------+------------+------------!
!    50.5181 !     1.0000 !     9.2954 !     0.0    !
!    53.0440 !     1.0000 !     5.0004 !     0.0    !
-----------------------------------------------------

HEATX HOT-TQCUR B23      TQCURV INLET
-------------------------------------
 PRESSURE PROFILE:      CONSTANT2
 PRESSURE DROP:         0.0         ATM
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

-----------------------------------------------------
! DUTY       ! PRES       ! TEMP       ! VFRAC      !
!            !            !            !            !
!            !            !            !            !
!            !            !            !            !
! KW         ! ATM        ! C          !            !
!            !            !            !            !
!============!============!============!============!
!     0.0    !     1.0000 !   103.3035 !     0.0    !
!     2.5259 !     1.0000 !   100.6096 !     0.0    !
!     5.0518 !     1.0000 !    97.9112 !     0.0    !
!     7.5777 !     1.0000 !    95.2085 !     0.0    !
!    10.1036 !     1.0000 !    92.5016 !     0.0    !
!------------+------------+------------+------------!
!    12.6295 !     1.0000 !    89.7904 !     0.0    !
!    15.1554 !     1.0000 !    87.0752 !     0.0    !
!    17.6813 !     1.0000 !    84.3559 !     0.0    !
!    20.2072 !     1.0000 !    81.6327 !     0.0    !
!    22.7331 !     1.0000 !    78.9056 !     0.0    !
!------------+------------+------------+------------!
!    25.2590 !     1.0000 !    76.1748 !     0.0    !
!    27.7849 !     1.0000 !    73.4404 !     0.0    !
!    30.3108 !     1.0000 !    70.7025 !     0.0    !
!    32.8367 !     1.0000 !    67.9611 !     0.0    !
!    35.3626 !     1.0000 !    65.2163 !     0.0    !
!------------+------------+------------+------------!
!    37.8886 !     1.0000 !    62.4683 !     0.0    !
!    40.4145 !     1.0000 !    59.7172 !     0.0    !
!    42.9404 !     1.0000 !    56.9631 !     0.0    !
!    45.4663 !     1.0000 !    54.2061 !     0.0    !
!    47.9922 !     1.0000 !    51.4463 !     0.0    !
!------------+------------+------------+------------!
!    50.5181 !     1.0000 !    48.6838 !     0.0    !
!    53.0440 !     1.0000 !    45.9187 !     0.0    !
-----------------------------------------------------

BLOCK:  B25      MODEL: MIXER
-----------------------------
 INLET STREAMS:         S32         S33
 OUTLET STREAM:         PURE
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                   IN              OUT        RELATIVE DIFF.
  TOTAL BALANCE
     MOLE(MOL/HR  )            16875.2         16875.2         0.00000
     MASS(KG/DAY  )            53847.7         53847.7         0.00000
     ENTHALPY(KW      )       -1304.84        -1304.84       -0.174254E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             0.00000      KG/DAY
  PRODUCT STREAMS CO2E          0.00000      KG/DAY
  NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
  UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
  TOTAL CO2E PRODUCTION         0.00000      KG/DAY

                         ***  INPUT DATA  ***
 TWO    PHASE      FLASH
 MAXIMUM NO. ITERATIONS                                    30
 CONVERGENCE TOLERANCE                                      0.000100000
 OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  CAOH-NEU MODEL: RSTOIC
------------------------------
 INLET STREAMS:         XYSUGARS    CAOH
 OUTLET STREAM:         SUGARSX
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                             IN           OUT        GENERATION   RELATIVE DIFF.
 TOTAL BALANCE
 MOLE(MOL/HR  )         362864.       363405.       541.036       0.00000
 MASS(KG/DAY  )         173166.       173166.                    -0.336138E-15
 ENTHALPY(KW      )    -29432.0      -30177.5                     0.247043E-01

                     ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             0.00000      KG/DAY
  PRODUCT STREAMS CO2E          0.00000      KG/DAY
  NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
```

```
 UTILITIES CO2E PRODUCTION     6206.90      KG/DAY
 TOTAL CO2E PRODUCTION         6206.90      KG/DAY

                      ***  INPUT DATA  ***
STOICHIOMETRY MATRIX:

 REACTION #   1:
  SUBSTREAM MIXED   :
  WATER      2.00    H2SO4     -1.00    CAOH2     -1.00    CASO4      1.00


REACTION CONVERSION SPECS: NUMBER=    1
  REACTION #   1:
  SUBSTREAM:MIXED    KEY COMP:CAOH2    CONV FRAC: 0.9500



TWO    PHASE  TP  FLASH
SPECIFIED TEMPERATURE C                                  25.0000
SPECIFIED PRESSURE    ATM                                 1.00000
MAXIMUM NO. ITERATIONS                                   30
CONVERGENCE TOLERANCE                                     0.000100000
SIMULTANEOUS REACTIONS
GENERATE COMBUSTION REACTIONS FOR FEED SPECIES          NO

                       ***  RESULTS  ***
OUTLET TEMPERATURE    C                                    25.000
OUTLET PRESSURE       ATM                                  1.0000
HEAT DUTY             KW                                 -745.51
VAPOR FRACTION                                             0.0000



REACTION EXTENTS:

   REACTION          REACTION
   NUMBER            EXTENT
                     MOL/HR
   1                  541.04

V-L PHASE EQUILIBRIUM :

   COMP             F(I)           X(I)           Y(I)           K(I)
   WATER           0.81783        0.81783        0.21826        0.12270E-01
   GLUCOSE         0.11775E-04    0.11775E-04    0.12650E-17    0.49526E-14
   XYLOSE          0.98894E-02    0.98894E-02    0.19065E-08    0.88814E-08
   OTHLIQUI        0.17061        0.17061        0.41383E-01    0.11152E-01
   H2SO4           0.90541E-04    0.90541E-04    0.59334E-12    0.30195E-09
   CAOH2           0.78358E-04    0.78358E-04    0.37018E-01     21.819
   CASO4           0.14888E-02    0.14888E-02    0.70334         21.819

                    ***  ASSOCIATED  UTILITIES  ***

UTILITY ID FOR ELECTRICITY                  ELEC
RATE OF CONSUMPTION                     745.5137  KW
COST                                     57.7773  $/HR
CO2 EQUIVALENT EMISSIONS               6206.9036  KG/DAY

BLOCK:  CHLMIX   MODEL: MIXER
-----------------------------
  INLET STREAMS:          PLA         CH2CL2IN
  OUTLET STREAM:          S7
  PROPERTY OPTION SET:    RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
```

```
                                   IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(MOL/HR  )            39255.3         39255.3         0.00000
    MASS(KG/DAY  )            90671.1         90671.1       -0.160491E-15
    ENTHALPY(KW      )       -1356.31        -1356.31        0.167641E-15

                    ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            696000.      KG/DAY
 PRODUCT STREAMS CO2E         696000.      KG/DAY
 NET STREAMS CO2E PRODUCTION   0.00000     KG/DAY
 UTILITIES CO2E PRODUCTION     0.00000     KG/DAY
 TOTAL CO2E PRODUCTION         0.00000     KG/DAY

                        ***  INPUT DATA  ***
ONE    PHASE      FLASH   SPECIFIED PHASE IS  LIQUID
MAXIMUM NO. ITERATIONS                                   30
CONVERGENCE TOLERANCE                                     0.000100000
OUTLET PRESSURE   ATM                                    1.00000

BLOCK:  CHROMA   MODEL: SEP
---------------------------
  INLET STREAM:          S28
  OUTLET STREAMS:        S18          S20
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                    ***  MASS AND ENERGY BALANCE  ***
                                   IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(MOL/HR  )            367691.         367691.         0.00000
    MASS(KG/DAY  )            173766.         173766.       -0.167489E-15
    ENTHALPY(KW      )       -30331.1        -30331.4        0.122095E-04

                    ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E             0.00000     KG/DAY
 PRODUCT STREAMS CO2E          0.00000     KG/DAY
 NET STREAMS CO2E PRODUCTION   0.00000     KG/DAY
 UTILITIES CO2E PRODUCTION     0.00000     KG/DAY
 TOTAL CO2E PRODUCTION         0.00000     KG/DAY


                        ***  INPUT DATA  ***

FLASH SPECS FOR STREAM S18
TWO    PHASE  TP  FLASH
PRESSURE DROP        ATM                                  0.0
MAXIMUM NO. ITERATIONS                                   30
CONVERGENCE TOLERANCE                                     0.000100000

FLASH SPECS FOR STREAM S20
TWO    PHASE  TP  FLASH
PRESSURE DROP        ATM                                  0.0
MAXIMUM NO. ITERATIONS                                   30
CONVERGENCE TOLERANCE                                     0.000100000

FRACTION OF FEED
  SUBSTREAM= MIXED
    STREAM= S18      CPT= OTHLIQUI  FRACTION=         1.00000
                          CASO4                       1.00000
                          OTHSOLID                    1.00000
                          CELLULOS                    1.00000


                         ***  RESULTS  ***

HEAT DUTY             KW                                 -0.37033
```

```
 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S20        MIXED                1.00000

 COMPONENT = XYLOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S20        MIXED                1.00000

 COMPONENT = OTHLIQUI
   STREAM     SUBSTREAM    SPLIT FRACTION
   S18        MIXED                1.00000

 COMPONENT = ENZ/XYL
   STREAM     SUBSTREAM    SPLIT FRACTION
   S20        MIXED                1.00000

BLOCK:  COOL2    MODEL: HEATER
------------------------------
  INLET STREAM:          S34
  OUTLET STREAM:         7
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                              IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )          30569.1         30569.1         0.00000
      MASS(KG/DAY  )          25010.3         25010.3         0.00000
      ENTHALPY(KW      )     -3197.97        -3235.16        0.114952E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    179.581      KG/DAY
   TOTAL CO2E PRODUCTION        179.581      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE              C                      5.00000
  SPECIFIED PRESSURE                 ATM                    1.00000
  MAXIMUM NO. ITERATIONS                                   30
  CONVERGENCE TOLERANCE                                     0.000100000



                    ***  RESULTS  ***
  OUTLET TEMPERATURE    C                               5.0000
  OUTLET PRESSURE       ATM                             1.0000
  HEAT DUTY             KW                             -37.189
  OUTLET VAPOR FRACTION                                 0.0000



  V-L PHASE EQUILIBRIUM :

     COMP             F(I)          X(I)          Y(I)          K(I)
     WATER           0.87992       0.87992       1.0000        0.74175E-02
     XYLOSE          0.15986E-01   0.15986E-01   0.12020E-09   0.49075E-10
     ENZ/XYL         0.10409       0.10409       0.14751E-08   0.92487E-10

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR REFRIGERANT            REFRIDGE
 RATE OF CONSUMPTION                  8.0328+05  KG/DAY
 COST                                    0.3668  $/HR
 CO2 EQUIVALENT EMISSIONS              179.5814  KG/DAY
```

```
BLOCK:  CRYSTALL MODEL: SEP
---------------------------
  INLET STREAM:          11
  OUTLET STREAMS:        LIQUOR      XYLITOL
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                              IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )          8084.44         8084.44         0.00000
      MASS(KG/DAY  )          12202.5         12202.5       -0.149066E-15
      ENTHALPY(KW      )     -1229.61        -1236.72        0.575138E-02

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM LIQUOR
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                                   0.0
  MAXIMUM NO. ITERATIONS                                     30
  CONVERGENCE TOLERANCE                                       0.000100000

  FLASH SPECS FOR STREAM XYLITOL
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                                   0.0
  MAXIMUM NO. ITERATIONS                                     30
  CONVERGENCE TOLERANCE                                       0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= XYLITOL   CPT= WATER     FRACTION=          0.0
                             GLUCOSE                      0.0
                             XYLOSE                       0.0
                             AMMONIA                      0.0
                             OTHLIQUI                     0.0
                             H2SO4                        0.0
                             CAOH2                        0.0
                             CASO4                        0.0
                             OTHSOLID                     0.0
                             CELLULOS                     0.0
                             ENZ/XYL                      1.00000
                             NACIT                        0.0
                             LACTICAC                     0.0
                             DIETHER                      0.0
                             N2                           0.0
                             METHANOL                     0.0
                             CH2CL2                       0.0
                             ETHYL-01                     0.0


                          ***  RESULTS  ***

  HEAT DUTY             KW                                   -7.1129

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   LIQUOR     MIXED                1.00000
```

```
 COMPONENT = ENZ/XYL
   STREAM     SUBSTREAM    SPLIT FRACTION
   XYLITOL    MIXED                1.00000

BLOCK:  DRYPLA   MODEL: FLASH2
------------------------------
  INLET STREAM:          S9
  OUTLET VAPOR STREAM:   STEAM2
  OUTLET LIQUID STREAM:  PLAREC
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           14557.0         14557.0         0.00000
      MASS(KG/DAY  )           52808.1         52808.1       -0.551124E-15
      ENTHALPY(KW      )       -313.283        -326.788        0.413254E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE C                                 99.8609
  SPECIFIED PRESSURE    ATM                                1.00000
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000

                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                  99.861
  OUTLET PRESSURE       ATM                                1.0000
  HEAT DUTY             KW                                -13.505
  VAPOR FRACTION                                           0.15955


  V-L PHASE EQUILIBRIUM :

     COMP             F(I)           X(I)           Y(I)           K(I)
     WATER           0.32541        0.19805        0.99628        5.0304
     GLUCOSE         0.22104E-02    0.26301E-02    0.45009E-08    0.17113E-05
     DIETHER         0.67199        0.79886        0.37247E-02    0.46625E-02
     PLA             0.38492E-03    0.45799E-03    0.41021E-26    0.89567E-23

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR WATER                  COOLINGW
 RATE OF CONSUMPTION                  5.5893+04  KG/DAY
 COST                                 1.0307-02  $/HR

BLOCK:  ETHFLASH MODEL: FLASH2
------------------------------
  INLET STREAM:          S14
  OUTLET VAPOR STREAM:   STEAM1
  OUTLET LIQUID STREAM:  ETHOUT1
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           14548.6         14548.6         0.00000
      MASS(KG/DAY  )           42137.1         42137.1       -0.155613E-11
```

```
      ENTHALPY(KW      )       -231.565        -259.275        0.106875

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    230.705      KG/DAY
   TOTAL CO2E PRODUCTION        230.705      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE C                                 157.480
  SPECIFIED PRESSURE    ATM                                1.00000
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000

                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                  157.48
  OUTLET PRESSURE       ATM                                1.0000
  HEAT DUTY             KW                                -27.710
  VAPOR FRACTION                                           0.29973


  V-L PHASE EQUILIBRIUM :

     COMP             F(I)           X(I)           Y(I)           K(I)
     WATER           0.32559        0.59889E-01    0.94636        15.802
     GLUCOSE         0.22104E-02    0.31560E-02    0.13313E-05    0.42182E-03
     DIETHER         0.67220        0.93695        0.53638E-01    0.57247E-01

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                  ELEC
 RATE OF CONSUMPTION                      27.7101  KW
 COST                                      2.1475  $/HR
 CO2 EQUIVALENT EMISSIONS                230.7053  KG/DAY

BLOCK:  EVAP     MODEL: FLASH2
------------------------------
  INLET STREAM:          S20
  OUTLET VAPOR STREAM:   STEAM4
  OUTLET LIQUID STREAM:  5
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           305689.         305689.       -0.754744E-06
      MASS(KG/DAY  )           143964.         143963.        0.379056E-05
      ENTHALPY(KW      )       -25227.1        -21428.5      -0.150578

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    21580.1      KG/DAY
   TOTAL CO2E PRODUCTION        21580.1      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  PV  FLASH
  SPECIFIED PRESSURE    ATM                                1.00000
  VAPOR FRACTION                                           0.90000
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000
```

```
                        ***  RESULTS  ***
OUTLET TEMPERATURE    C                              103.30
OUTLET PRESSURE       ATM                            1.0000
HEAT DUTY             KW                             3798.6
VAPOR FRACTION                                      0.90000


V-L PHASE EQUILIBRIUM :

   COMP             F(I)           X(I)           Y(I)           K(I)
   WATER          0.98799        0.87991        1.0000         1.1365
   XYLOSE         0.15988E-02    0.15987E-01    0.83958E-07    0.52515E-05
   ENZ/XYL        0.10410E-01    0.10410        0.39305E-06    0.37756E-05

                    ***  ASSOCIATED  UTILITIES  ***

UTILITY ID FOR STEAM                    LPSTEAM
RATE OF CONSUMPTION                   1.4973+05  KG/DAY
COST                                    25.9825  $/HR
CO2 EQUIVALENT EMISSIONS              2.1580+04  KG/DAY

BLOCK:  EVAP2    MODEL: FLASH2
------------------------------
  INLET STREAM:          S5
  OUTLET VAPOR STREAM:   STEAM3
  OUTLET LIQUID STREAM:  4
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           780116.        780116.       -0.298457E-15
      MASS(KG/DAY  )           352906.        352906.       -0.494815E-15
      ENTHALPY(KW      )      -59485.9       -60845.4        0.223443E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    11319.2      KG/DAY
   TOTAL CO2E PRODUCTION        11319.2      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TV  FLASH
  SPECIFIED TEMPERATURE C                          110.000
  VAPOR FRACTION                                     0.100000
  MAXIMUM NO. ITERATIONS                            30
  CONVERGENCE TOLERANCE                              0.000100000

                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                              110.00
  OUTLET PRESSURE       ATM                            1.2993
  HEAT DUTY             KW                            -1359.5
  VAPOR FRACTION                                      0.10000


  V-L PHASE EQUILIBRIUM :

     COMP             F(I)           X(I)           Y(I)           K(I)
     WATER          0.98933        0.98827        0.99890        1.0108
     OTHSOLID       0.61292E-02    0.66883E-02    0.10969E-02    0.16400
     CELLULOS       0.45370E-02    0.50411E-02    0.71406E-08    0.14165E-05
     ENZ/XYL        0.13941E-06    0.15490E-06    0.45692E-11    0.29497E-04
     DIETHER        0.60580E-10    0.38726E-14    0.60577E-09    0.15642E+06
```

```
                       ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                  ELEC
 RATE OF CONSUMPTION                    1359.5488  KW
 COST                                    105.3650  $/HR
 CO2 EQUIVALENT EMISSIONS               1.1319+04  KG/DAY

BLOCK:  FILTER   MODEL: SEP
---------------------------
  INLET STREAM:          PROD-C
  OUTLET STREAMS:        XYSUGARS    S5
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )         0.112766E+07    0.112766E+07    0.206472E-15
      MASS(KG/DAY  )          518683.         518683.        0.112222E-15
      ENTHALPY(KW      )     -89770.2        -87643.8       -0.236868E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY


                       ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM XYSUGARS
  TWO    PHASE  TP  FLASH
  PRESSURE DROP          ATM                             0.0
  MAXIMUM NO. ITERATIONS                                30
  CONVERGENCE TOLERANCE                                  0.000100000

  FLASH SPECS FOR STREAM S5
  TWO    PHASE  TP  FLASH
  PRESSURE DROP          ATM                             0.0
  MAXIMUM NO. ITERATIONS                                30
  CONVERGENCE TOLERANCE                                  0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= XYSUGARS  CPT= WATER     FRACTION=         0.26717
                             GLUCOSE                     1.00000
                             XYLOSE                      1.00000
                             AMMONIA                     0.0
                             OTHLIQUI                    1.00000
                             H2SO4                       1.00000
                             CAOH2                       0.0
                             CASO4                       0.0
                             OTHSOLID                    0.0
                             CELLULOS                    0.0
                             ENZ/XYL                     0.0
                             NACIT                       0.0


                        ***  RESULTS  ***

  HEAT DUTY             KW                                2126.4

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   XYSUGARS   MIXED                0.26717
```

```
  S5         MIXED                0.73283

 COMPONENT = GLUCOSE
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYSUGARS   MIXED                1.00000

 COMPONENT = XYLOSE
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYSUGARS   MIXED                1.00000

 COMPONENT = OTHLIQUI
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYSUGARS   MIXED                1.00000

 COMPONENT = H2SO4
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYSUGARS   MIXED                1.00000

 COMPONENT = OTHSOLID
  STREAM     SUBSTREAM    SPLIT FRACTION
  S5         MIXED                1.00000

 COMPONENT = CELLULOS
  STREAM     SUBSTREAM    SPLIT FRACTION
  S5         MIXED                1.00000

 COMPONENT = ENZ/XYL
  STREAM     SUBSTREAM    SPLIT FRACTION
  S5         MIXED                1.00000

 COMPONENT = DIETHER
  STREAM     SUBSTREAM    SPLIT FRACTION
  S5         MIXED                1.00000

BLOCK:  FILTER2  MODEL: SEP
---------------------------
  INLET STREAM:          7
  OUTLET STREAMS:        8           9
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           30569.1         30569.7       -0.193705E-04
      MASS(KG/DAY  )           25010.3         25010.6       -0.127197E-04
      ENTHALPY(KW      )       -3235.16        -3241.76        0.203384E-02

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY


                       ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM 8
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                               0.0
  MAXIMUM NO. ITERATIONS                                30
  CONVERGENCE TOLERANCE                                   0.000100000

  FLASH SPECS FOR STREAM 9
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                               0.0
  MAXIMUM NO. ITERATIONS                                30
  CONVERGENCE TOLERANCE                                   0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= 9         CPT= WATER     FRACTION=          0.20000
                             GLUCOSE                      0.0
                             XYLOSE                       0.0
                             AMMONIA                      0.0
                             OTHLIQUI                     0.0
                             H2SO4                        0.0
                             CAOH2                        0.0
                             CASO4                        0.0
                             OTHSOLID                     0.0
                             CELLULOS                     0.0
                             ENZ/XYL                      0.85000
                             NACIT                        0.0
                             LACTICAC                     0.0
                             DIETHER                      0.0
                             N2                           0.0
                             METHANOL                     0.0
                             CH2CL2                       0.0
                             ETHYL-01                     0.0


                        ***  RESULTS  ***

  HEAT DUTY             KW                                  -6.5417

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   8          MIXED                0.80000
   9          MIXED                0.20000

 COMPONENT = XYLOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   8          MIXED                1.00000

 COMPONENT = ENZ/XYL
   STREAM     SUBSTREAM    SPLIT FRACTION
   8          MIXED                0.15000
   9          MIXED                0.85000

BLOCK:  FUGEPLA  MODEL: SEP
---------------------------
  INLET STREAM:          SUGARSP
  OUTLET STREAMS:        PLASUGAR    PREC-PLA
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           885671.         885671.        0.131443E-15
      MASS(KG/DAY  )           420005.         420005.        0.00000
      ENTHALPY(KW      )       -73175.8        -73175.9        0.732725E-06

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY


                       ***  INPUT DATA  ***
```

```
 FLASH SPECS FOR STREAM PLASUGAR
 TWO    PHASE  TP  FLASH
 PRESSURE DROP         ATM                                 0.0
 MAXIMUM NO. ITERATIONS                                   30
 CONVERGENCE TOLERANCE                                     0.000100000

 FLASH SPECS FOR STREAM PREC-PLA
 TWO    PHASE  TP  FLASH
 PRESSURE DROP         ATM                                 0.0
 MAXIMUM NO. ITERATIONS                                   30
 CONVERGENCE TOLERANCE                                     0.000100000

 FRACTION OF FEED
   SUBSTREAM= MIXED
     STREAM= PLASUGAR  CPT= WATER     FRACTION=          0.95000
                            GLUCOSE                      1.00000
                            XYLOSE                       1.00000
                            AMMONIA                      0.0
                            OTHLIQUI                     1.00000
                            H2SO4                        0.0
                            CAOH2                        0.0
                            CASO4                        0.0
                            OTHSOLID                     0.0
                            CELLULOS                     0.0
                            ENZ/XYL                      0.0
                            NACIT                        0.0


                        ***  RESULTS  ***

 HEAT DUTY             KW                                 -0.53618E-01

COMPONENT = WATER
  STREAM     SUBSTREAM    SPLIT FRACTION
  PLASUGAR   MIXED                 0.95000
  PREC-PLA   MIXED                 0.050000

COMPONENT = GLUCOSE
  STREAM     SUBSTREAM    SPLIT FRACTION
  PLASUGAR   MIXED                 1.00000

COMPONENT = AMMONIA
  STREAM     SUBSTREAM    SPLIT FRACTION
  PREC-PLA   MIXED                 1.00000

COMPONENT = OTHSOLID
  STREAM     SUBSTREAM    SPLIT FRACTION
  PREC-PLA   MIXED                 1.00000

COMPONENT = ENZ/XYL
  STREAM     SUBSTREAM    SPLIT FRACTION
  PREC-PLA   MIXED                 1.00000

COMPONENT = NACIT
  STREAM     SUBSTREAM    SPLIT FRACTION
  PREC-PLA   MIXED                 1.00000

BLOCK:  FUGEXYL  MODEL: SEP
---------------------------
 INLET STREAM:          SUGARSX
 OUTLET STREAMS:        XYLSUGAR    PREC-XYL
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
  TOTAL BALANCE
    MOLE(MOL/HR )           363405.         363405.       -0.160173E-15
    MASS(KG/DAY )           173166.         173166.        0.336138E-15
    ENTHALPY(KW      )     -30177.5        -30195.5        0.595726E-03

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY


                         ***  INPUT DATA  ***

 FLASH SPECS FOR STREAM XYLSUGAR
 TWO    PHASE  TP  FLASH
 PRESSURE DROP         ATM                                 0.0
 MAXIMUM NO. ITERATIONS                                   30
 CONVERGENCE TOLERANCE                                     0.000100000

 FLASH SPECS FOR STREAM PREC-XYL
 TWO    PHASE  TP  FLASH
 PRESSURE DROP         ATM                                 0.0
 MAXIMUM NO. ITERATIONS                                   30
 CONVERGENCE TOLERANCE                                     0.000100000

 FRACTION OF FEED
   SUBSTREAM= MIXED
     STREAM= XYLSUGAR  CPT= WATER     FRACTION=          0.98000
                            GLUCOSE                      1.00000
                            XYLOSE                       1.00000
                            AMMONIA                      0.0
                            OTHLIQUI                     1.00000
                            H2SO4                        0.0
                            CAOH2                        0.0
                            CASO4                        0.0
                            OTHSOLID                     0.0
                            CELLULOS                     0.0
                            ENZ/XYL                      0.0
                            NACIT                        0.0


                         ***  RESULTS  ***

 HEAT DUTY             KW                                 -17.988

COMPONENT = WATER
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYLSUGAR   MIXED                 0.98000
  PREC-XYL   MIXED                 0.020000

COMPONENT = GLUCOSE
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYLSUGAR   MIXED                 1.00000

COMPONENT = XYLOSE
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYLSUGAR   MIXED                 1.00000

COMPONENT = OTHLIQUI
  STREAM     SUBSTREAM    SPLIT FRACTION
  XYLSUGAR   MIXED                 1.00000

COMPONENT = H2SO4
  STREAM     SUBSTREAM    SPLIT FRACTION
  PREC-XYL   MIXED                 1.00000
```

```
 COMPONENT = CAOH2
   STREAM     SUBSTREAM    SPLIT FRACTION
   PREC-XYL   MIXED                 1.00000

 COMPONENT = CASO4
   STREAM     SUBSTREAM    SPLIT FRACTION
   PREC-XYL   MIXED                 1.00000

BLOCK:  LLE      MODEL: EXTRACT
-------------------------------

   INLETS   - S16      STAGE   1
              ETHIN2   STAGE   5
   OUTLETS  - S33      STAGE   1
              S31      STAGE   5
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           832675.         832675.       -0.139809E-15
      MASS(KG/DAY  )           406931.         406931.        0.143040E-15
      ENTHALPY(KW      )       -66438.5        -66805.9        0.550051E-02

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY



                      **********************
                      ****  INPUT DATA  ****
                      **********************

  ****   INPUT PARAMETERS   ****

   NUMBER OF THEORETICAL STAGES                              5
   MAXIMUM NO. OF OUTSIDE LOOPS                             25
   MAXIMUM NO. OF INSIDE LOOPS PER OUTSIDE LOOP             10
   OUTSIDE LOOP CONVERGENCE TOLERANCE                        0.000100000
   QMIN FOR BOUNDED WEGSTEIN IN OUTSIDE LOOP                 0.0
   QMAX FOR BOUNDED WEGSTEIN IN OUTSIDE LOOP                 0.50000
   QMIN FOR BOUNDED WEGSTEIN IN INSIDE LOOP                  0.0
   QMAX FOR BOUNDED WEGSTEIN IN INSIDE LOOP                  0.50000
   OUTSIDE LOOP ERROR THRESHOLD FOR BROYDEN METHOD           0.100000


  ****   KEY COMPONENT SPECIFICATIONS   ****

   KEY COMPONENTS FOR LIQUID1                  WATER

   KEY COMPONENTS FOR LIQUID2                  LACTICAC
                                               DIETHER


  ****    PROFILES   ****

   TEMP-SPEC       STAGE   1  TEMP  C                        34.5000
                           2                                 31.8000
                           3                                 29.0000
                           4                                 26.0000
                           5                                 22.7000
```

```
 P-SPEC          STAGE   1  PRES  ATM                    1.00000
                         2                               1.00000
                         3                               1.00000
                         4                               1.00000
                         5                               1.00000

                       *******************
                       ****  RESULTS  ****
                       *******************


***   COMPONENT SPLIT FRACTIONS   ***

                          OUTLET STREAMS
                          --------------
              S33          S31
 COMPONENT:
 WATER       .10873E-02   .99891
 GLUCOSE     .15580E-04   .99998
 LACTICAC    .34822       .65178
 DIETHER    1.0000        .54353E-11



                       *******************
                       ****  RESULTS  ****
                       *******************

 TOP STAGE TEMPERATURE            C                    34.5000
 BOTTOM STAGE TEMPERATURE         C                    22.7000
 TOP STAGE LIQUID1 FLOW           MOL/HR          823,114.
 BOTTOM STAGE LIQUID1 FLOW        MOL/HR          819,777.
 TOP STAGE LIQUID2 FLOW           MOL/HR           12,898.1
 BOTTOM STAGE LIQUID2 FLOW        MOL/HR           11,950.6

****   MAXIMUM FINAL RELATIVE ERRORS   ****,

 L1 BUBBLE POINT ERROR          0.91371E-06  STAGE=  2
 L2 BUBBLE POINT ERROR          0.10697E-05  STAGE=  4
 COMPONENT MASS BALANCE         0.47830E-15  STAGE=  2 COMP=DIETHER
 ENERGY BALANCE                 0.15117E-16  STAGE=  5


****    PROFILES   ****

                                              ENTHALPY
STAGE TEMPERATURE   PRESSURE               KJ/MOL             HEAT DUTY
     C              ATM           LIQUID1       LIQUID2      KW

  1   34.500        1.0000       -291.21      -145.54        -47.0485
  2   31.800        1.0000       -291.49      -156.22        -51.4745
  3   29.000        1.0000       -291.62      -159.96        -54.3651
  4   26.000        1.0000       -291.53      -149.38        -59.5952
  5   22.700        1.0000       -291.08      -115.10       -154.9836

STAGE     FLOW RATE                   FEED RATE              PRODUCT RATE
           MOL/HR                      MOL/HR                  MOL/HR
    LIQUID1     LIQUID2                                    LIQUID1    LIQUID2
  1 0.8231E+06 0.1290E+05            .82288+06                          .12898+05
  2 0.8232E+06 0.1313E+05
  3 0.8228E+06 0.1317E+05
  4 0.8219E+06 0.1283E+05
  5 0.8198E+06 0.1195E+05            9791.7797            .81978+06
```

```
 ****  MASS FLOW PROFILES  ****

STAGE     FLOW RATE                  FEED RATE               PRODUCT RATE
            KG/DAY                     KG/DAY                    KG/DAY
    LIQUID1     LIQUID2                                  LIQUID1    LIQUID2
  1 0.3675E+06 0.4518E+05            .36693+06                     .45180+05
  2 0.3676E+06 0.4570E+05
  3 0.3670E+06 0.4587E+05
  4 0.3654E+06 0.4529E+05
  5 0.3618E+06 0.4363E+05            .40000+05            .36175+06

                        ****   LIQUID1 PROFILE    ****
  STAGE     WATER         GLUCOSE       LACTICAC      DIETHER
     1     0.99192       0.39092E-04   0.80388E-02   0.92455E-12
     2     0.99182       0.39090E-04   0.81423E-02   0.56926E-12
     3     0.99212       0.39106E-04   0.78394E-02   0.32283E-12
     4     0.99301       0.39148E-04   0.69512E-02   0.16101E-12
     5     0.99490       0.39251E-04   0.50655E-02   0.64921E-13

                        ****   LIQUID2 PROFILE    ****
  STAGE     WATER         GLUCOSE       LACTICAC      DIETHER
     1     0.68831E-01   0.38869E-07   0.17200       0.75916
     2     0.66509E-01   0.35751E-07   0.18769       0.74580
     3     0.63191E-01   0.30822E-07   0.19355       0.74326
     4     0.57900E-01   0.22977E-07   0.17906       0.76304
     5     0.50039E-01   0.13556E-07   0.13061       0.81936

                        ****   K-VALUES           ****
  STAGE     WATER         GLUCOSE       LACTICAC      DIETHER
     1     0.69392E-01   0.99428E-03    21.397       0.82112E+12
     2     0.67057E-01   0.91458E-03    23.051       0.13101E+13
     3     0.63693E-01   0.78817E-03    24.689       0.23023E+13
     4     0.58308E-01   0.58692E-03    25.760       0.47390E+13
     5     0.50295E-01   0.34537E-03    25.783       0.12621E+14

                        ****   MASS-X1-PROFILE    ****
  STAGE     WATER         GLUCOSE       LACTICAC      DIETHER
     1     0.96069       0.37862E-03   0.38929E-01   0.84602E-11
     2     0.96021       0.37845E-03   0.39415E-01   0.52070E-11
     3     0.96163       0.37905E-03   0.37993E-01   0.29564E-11
     4     0.96581       0.38077E-03   0.33805E-01   0.14796E-11
     5     0.97480       0.38459E-03   0.24817E-01   0.60099E-12

                        ****   MASS-X2-PROFILE    ****
  STAGE     WATER         GLUCOSE       LACTICAC      DIETHER
     1     0.84960E-02   0.47978E-07   0.10616       0.88535
     2     0.82605E-02   0.44404E-07   0.11656       0.87518
     3     0.78465E-02   0.38273E-07   0.12017       0.87198
     4     0.70934E-02   0.28150E-07   0.10969       0.88322
     5     0.59256E-02   0.16053E-07   0.77335E-01   0.91674

BLOCK:  LLEREC   MODEL: SEP
---------------------------
  INLET STREAM:            S31
  OUTLET STREAMS:          WASTE       S32
  PROPERTY OPTION SET:     RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                   IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )            819777.         819777.         0.00000
      MASS(KG/DAY  )            361751.         361751.         0.00000
      ENTHALPY(KW      )       -66284.5        -66310.4        0.390505E-03

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E             0.00000      KG/DAY
   PRODUCT STREAMS CO2E          0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
   TOTAL CO2E PRODUCTION         0.00000      KG/DAY

                         ***  INPUT DATA  ***

  FLASH SPECS FOR STREAM WASTE
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                                  0.0
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000

  FLASH SPECS FOR STREAM S32
  TWO    PHASE  TP  FLASH
  PRESSURE DROP         ATM                                  0.0
  MAXIMUM NO. ITERATIONS                                    30
  CONVERGENCE TOLERANCE                                      0.000100000

  FRACTION OF FEED
    SUBSTREAM= MIXED
      STREAM= S32       CPT= WATER     FRACTION=          0.0
                             LACTICAC                     0.95000

                          ***  RESULTS  ***

  HEAT DUTY             KW                                   -25.895

 COMPONENT = WATER
   STREAM     SUBSTREAM    SPLIT FRACTION
   WASTE      MIXED                1.00000

 COMPONENT = GLUCOSE
   STREAM     SUBSTREAM    SPLIT FRACTION
   S32        MIXED                1.00000

 COMPONENT = LACTICAC
   STREAM     SUBSTREAM    SPLIT FRACTION
   WASTE      MIXED                0.050000
   S32        MIXED                0.95000

 COMPONENT = DIETHER
   STREAM     SUBSTREAM    SPLIT FRACTION
   S32        MIXED                1.00000

BLOCK:  PLA-FERM MODEL: RYIELD
------------------------------
  INLET STREAM:          S21
  OUTLET STREAM:         1
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

    ***********************************************************************
    *                                                                     *
    *     SPECIFIED YIELDS HAVE BEEN NORMALIZED TO MAINTAIN MASS BALANCE  *
    *                                                                     *
    ***********************************************************************

                     ***  MASS AND ENERGY BALANCE  ***
                            IN          OUT       GENERATION   RELATIVE DIFF.
  TOTAL BALANCE
```

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 MOLE(MOL/HR )         820019.       824587.       4568.04      0.141180E-15
 MASS(KG/DAY )         368323.       368323.                    0.474103E-15
 ENTHALPY(KW      )    -66538.5      -66579.1                   0.609218E-03

                   ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             0.00000      KG/DAY
  PRODUCT STREAMS CO2E          0.00000      KG/DAY
  NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
  UTILITIES CO2E PRODUCTION     337.699      KG/DAY
  TOTAL CO2E PRODUCTION         337.699      KG/DAY

                       ***  INPUT DATA  ***
 TWO    PHASE  TP  FLASH
 SPECIFIED TEMPERATURE C                                  37.0000
 SPECIFIED PRESSURE    ATM                                 1.00000
 MAXIMUM NO. ITERATIONS                                   30
 CONVERGENCE TOLERANCE                                     0.000100000

  MASS-YIELD
   SUBSTREAM MIXED   :
   GLUCOSE   0.100E-01    OTHSOLID  0.100        LACTICAC  0.990

 INERTS:        WATER      OTHLIQUI   ENZ/XYL    NACIT

                        ***  RESULTS  ***
 OUTLET TEMPERATURE    C                                  37.000
 OUTLET PRESSURE       ATM                                 1.0000
 HEAT DUTY             KW                                -40.561
 VAPOR FRACTION                                            0.0000


 V-L PHASE EQUILIBRIUM :

    COMP             F(I)           X(I)           Y(I)           K(I)
    WATER           0.99017        0.99017        0.99968        0.48859E-01
    GLUCOSE         0.39022E-04    0.39022E-04    0.10773E-15    0.13360E-12
    OTHSOLID        0.20668E-02    0.20668E-02    0.17657E-03    0.41344E-02
    LACTICAC        0.77264E-02    0.77264E-02    0.14396E-03    0.90170E-03

                    ***  ASSOCIATED  UTILITIES  ***

UTILITY ID FOR ELECTRICITY                 ELEC
RATE OF CONSUMPTION                     40.5612  KW
COST                                     3.1435  $/HR
CO2 EQUIVALENT EMISSIONS               337.6993  KG/DAY

BLOCK:  PLAFLASH MODEL: FLASH2
------------------------------
  INLET STREAM:          S24
  OUTLET VAPOR STREAM:   ETHPLA
  OUTLET LIQUID STREAM:  PLA
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
  TOTAL BALANCE
     MOLE(MOL/HR  )           14557.0         14557.0         0.00000
     MASS(KG/DAY  )           52808.1         52808.1        0.118353E-09
     ENTHALPY(KW      )       1.45976         1.45976       -0.572222E-08

                   ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             0.00000      KG/DAY
  PRODUCT STREAMS CO2E          0.00000      KG/DAY
  NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
  UTILITIES CO2E PRODUCTION     0.00000      KG/DAY
```

```
  TOTAL CO2E PRODUCTION         0.00000      KG/DAY

                      ***  INPUT DATA  ***
 TWO    PHASE  TP  FLASH
 SPECIFIED TEMPERATURE C                                 288.000
 SPECIFIED PRESSURE    ATM                                 1.00000
 MAXIMUM NO. ITERATIONS                                   40
 CONVERGENCE TOLERANCE                                     0.0050000

                        ***  RESULTS  ***
 OUTLET TEMPERATURE    C                                 288.00
 OUTLET PRESSURE       ATM                                 1.0000
 HEAT DUTY             KW                                  0.83530E-08
 VAPOR FRACTION                                            0.99943


 V-L PHASE EQUILIBRIUM :

    COMP             F(I)           X(I)           Y(I)           K(I)
    WATER           0.32541        0.53131E-02    0.32559        61.281
    GLUCOSE         0.22104E-02    0.22407E-02    0.22104E-02    0.98650
    DIETHER         0.67199        0.32085        0.67220         2.0951
    PLA             0.38492E-03    0.67160        0.29359E-24    0.43715E-24

BLOCK:  POLYHEAT MODEL: HEATER
------------------------------
  INLET STREAM:          2
  OUTLET STREAM:         S3
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                IN              OUT        RELATIVE DIFF.
  TOTAL BALANCE
     MOLE(MOL/HR  )           16875.2         16875.2         0.00000
     MASS(KG/DAY  )           53847.7         53847.7         0.00000
     ENTHALPY(KW      )      -1227.78        -1133.35       -0.769064E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
  FEED STREAMS CO2E             0.00000      KG/DAY
  PRODUCT STREAMS CO2E          0.00000      KG/DAY
  NET STREAMS CO2E PRODUCTION   0.00000      KG/DAY
  UTILITIES CO2E PRODUCTION     786.143      KG/DAY
  TOTAL CO2E PRODUCTION         786.143      KG/DAY

                      ***  INPUT DATA  ***
 TWO    PHASE  TP  FLASH
 SPECIFIED TEMPERATURE               C                        170.000
 SPECIFIED PRESSURE                  ATM                        1.00000
 MAXIMUM NO. ITERATIONS                                        30
 CONVERGENCE TOLERANCE                                          0.000100000



                        ***  RESULTS  ***
 OUTLET TEMPERATURE    C                                 170.00
 OUTLET PRESSURE       ATM                               1.0000
 HEAT DUTY             KW                                94.424
 OUTLET VAPOR FRACTION                                   0.0000


 V-L PHASE EQUILIBRIUM :

    COMP             F(I)           X(I)           Y(I)           K(I)
    WATER           0.52609E-01    0.52609E-01    0.89338        16.763
```

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   GLUCOSE        0.19068E-02    0.19068E-02    0.96657E-06    0.50041E-03
   LACTICAC       0.36524        0.36524        0.48965E-01    0.13234
   DIETHER        0.58025        0.58025        0.57657E-01    0.98090E-01

                  ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                 ELEC
 RATE OF CONSUMPTION                     94.4240  KW
 COST                                     7.3179  $/HR
 CO2 EQUIVALENT EMISSIONS               786.1430  KG/DAY

BLOCK:  POLYREAC MODEL: RSTOIC
------------------------------
  INLET STREAMS:         S3          PLAREC
  OUTLET STREAM:         PLA1
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                             IN          OUT       GENERATION   RELATIVE DIFF.
  TOTAL BALANCE
  MOLE(MOL/HR  )         29109.6       29115.2       5.60316     -0.374854E-15
  MASS(KG/DAY  )         105620.       105620.                   -0.137776E-15
  ENTHALPY(KW      )    -1306.45      -489.692                   -0.625172

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    4640.02      KG/DAY
   TOTAL CO2E PRODUCTION        4640.02      KG/DAY

                         ***  INPUT DATA  ***
  STOICHIOMETRY MATRIX:

   REACTION #   1:
    SUBSTREAM MIXED   :
    WATER     0.110E+04LACTICAC -0.110E+04PLA        1.00


  REACTION CONVERSION SPECS: NUMBER=    1
    REACTION #   1:
    SUBSTREAM:MIXED    KEY COMP:LACTICAC CONV FRAC:  1.000



  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE C                              170.000
  SPECIFIED PRESSURE    ATM                              1.00000
  MAXIMUM NO. ITERATIONS                               30
  CONVERGENCE TOLERANCE                                  0.000100000
  SIMULTANEOUS REACTIONS
  GENERATE COMBUSTION REACTIONS FOR FEED SPECIES       NO

                          ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                 170.00
  OUTLET PRESSURE       ATM                               1.0000
  HEAT DUTY             KW                                816.75
  VAPOR FRACTION                                         0.32022


  REACTION EXTENTS:

     REACTION          REACTION
     NUMBER            EXTENT
                     MOL/HR
     1                5.6032

  V-L PHASE EQUILIBRIUM :

     COMP              F(I)           X(I)           Y(I)           K(I)
     WATER           0.32541        0.47467E-01    0.91543        19.286
     GLUCOSE         0.22103E-02    0.32498E-02    0.36433E-05    0.11211E-02
     DIETHER         0.67200        0.94872        0.84562E-01    0.89133E-01
     PLA             0.38490E-03    0.56621E-03    0.28394E-27    0.50147E-24

                     ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR STEAM                     HPSTEAM
 RATE OF CONSUMPTION                    4.1044+04  KG/DAY
 COST                                      7.3508  $/HR
 CO2 EQUIVALENT EMISSIONS               4640.0209  KG/DAY

BLOCK:  PSPLIT   MODEL: FSPLIT
------------------------------
  INLET STREAM:          S4
  OUTLET STREAMS:        S9          S12
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT         RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           29115.2         29113.9        0.423561E-04
      MASS(KG/DAY  )           105620.         105616.        0.357704E-04
      ENTHALPY(KW      )      -626.585        -626.566       -0.302746E-04

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***

 FRACTION OF FLOW                STRM=S9       FRAC=         0.50000

                          ***  RESULTS  ***

 STREAM= S9             SPLIT=          0.50000     KEY=  0    STREAM-ORDER=  1
         S12                            0.50000           0                   2

BLOCK:  SA-HYDRO MODEL: RYIELD
------------------------------
  INLET STREAMS:         WETBSGH     S11
  OUTLET STREAM:         PROD-H
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

    ***********************************************************************
    *                                                                     *
    *     ELEMENTS ARE NOT IN ATOM BALANCE                                *
    *                                                                     *
    ***********************************************************************


                     ***  MASS AND ENERGY BALANCE  ***
                             IN          OUT       GENERATION   RELATIVE DIFF.
  TOTAL BALANCE
  MOLE(MOL/HR  )       0.106808E+07  0.112766E+07   59587.4     -0.769872E-07
  MASS(KG/DAY  )         518683.       518683.                   -0.717271E-06
```

```
ENTHALPY(KW      )    -74512.3      -76232.0                   0.225589E-01

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***
TWO    PHASE  TP  FLASH
SPECIFIED TEMPERATURE C                              150.000
SPECIFIED PRESSURE    ATM                              1.00000
MAXIMUM NO. ITERATIONS                                30
CONVERGENCE TOLERANCE                                  0.000100000

 MASS-YIELD
  SUBSTREAM MIXED   :
  XYLOSE    0.209        OTHLIQUI  0.481        OTHSOLID  0.630E-01
  CELLULOS  0.247

INERTS:        WATER      H2SO4      ENZ/XYL    DIETHER    GLUCOSE


                        ***  RESULTS  ***
OUTLET TEMPERATURE    C                                 150.00
OUTLET PRESSURE       ATM                               1.0000
HEAT DUTY             KW                               -1719.7
VAPOR FRACTION                                         0.99170


V-L PHASE EQUILIBRIUM :

   COMP              F(I)           X(I)           Y(I)           K(I)
   WATER            0.93394        0.16928        0.94034         5.5549
   GLUCOSE          0.37191E-05    0.44747E-03    0.28438E-08    0.63552E-05
   XYLOSE           0.31870E-02    0.37855        0.43504E-04    0.11492E-03
   OTHLIQUI         0.54983E-01    0.10248E-01    0.55358E-01    5.4019
   H2SO4            0.50896E-03    0.60961E-01    0.27120E-05    0.44487E-04
   OTHSOLID         0.42402E-02    0.29239E-02    0.42512E-02    1.4540
   CELLULOS         0.31387E-02    0.37757        0.30044E-05    0.79572E-05
   ENZ/XYL          0.95923E-07    0.11477E-04    0.61238E-09    0.53357E-04
   DIETHER          0.28031E-10    0.58742E-11    0.28217E-10     4.8035

BLOCK:  SACCH    MODEL: RYIELD
------------------------------
 INLET STREAMS:         NACIT       ENZYMES     SACHIN
 OUTLET STREAM:         SUGARSP
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE


   **********************************************************************
   *                                                                    *
   *     ELEMENTS ARE NOT IN ATOM BALANCE                               *
   *                                                                    *
   **********************************************************************


                   ***  MASS AND ENERGY BALANCE  ***
                           IN          OUT       GENERATION   RELATIVE DIFF.
 TOTAL BALANCE
 MOLE(MOL/HR  )         913971.       885671.      -28300.3     -0.254746E-15
 MASS(KG/DAY  )         420005.       420005.                   -0.277176E-15
 ENTHALPY(KW      )    -73684.6      -73175.8                   -0.690493E-02

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***
TWO    PHASE  TP  FLASH
SPECIFIED TEMPERATURE C                                 25.0000
SPECIFIED PRESSURE    ATM                                1.00000
MAXIMUM NO. ITERATIONS                                  30
CONVERGENCE TOLERANCE                                    0.000100000

 MASS-YIELD
  SUBSTREAM MIXED   :
  GLUCOSE    1.00

INERTS:        WATER      AMMONIA    OTHSOLID   ENZ/XYL    NACIT


                        ***  RESULTS  ***
OUTLET TEMPERATURE    C                                  25.000
OUTLET PRESSURE       ATM                                1.0000
HEAT DUTY             KW                                 508.79
VAPOR FRACTION                                         0.11531E-01


V-L PHASE EQUILIBRIUM :

   COMP              F(I)           X(I)           Y(I)           K(I)
   WATER            0.97040        0.98146        0.22391E-01    0.22814E-01
   GLUCOSE          0.39964E-02    0.40430E-02    0.32170E-16    0.79568E-14
   AMMONIA          0.11272E-01    0.90083E-20    0.97760        0.10852E+21
   OTHSOLID         0.53021E-02    0.53638E-02    0.90122E-05    0.16802E-02
   ENZ/XYL          0.48456E-02    0.49021E-02    0.38949E-09    0.79453E-07
   NACIT            0.41867E-02    0.42356E-02    0.19256E-32    0.45462E-30

BLOCK:  SPLIT    MODEL: FSPLIT
------------------------------
 INLET STREAM:          S36
 OUTLET STREAMS:        PURGE       RECYCLE
 PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                   ***  MASS AND ENERGY BALANCE  ***
                                 IN              OUT        RELATIVE DIFF.
 TOTAL BALANCE
    MOLE(MOL/HR  )            22485.3         22485.3         0.00000
    MASS(KG/DAY  )            12808.0         12808.0         0.00000
    ENTHALPY(KW      )       -1959.10        -1959.10         0.00000

                   ***  CO2 EQUIVALENT SUMMARY ***
 FEED STREAMS CO2E            0.00000      KG/DAY
 PRODUCT STREAMS CO2E         0.00000      KG/DAY
 NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
 UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
 TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***

FRACTION OF FLOW                 STRM=PURGE    FRAC=         0.50000

                        ***  RESULTS  ***

STREAM= PURGE          SPLIT=          0.50000     KEY=  0    STREAM-ORDER=   1
```

```
        RECYCLE                         0.50000          0                    2

BLOCK:  WASH     MODEL: MIXER
-----------------------------
  INLET STREAMS:          BSG         S2
  OUTLET STREAM:          WETBSGC
  PROPERTY OPTION SET:    RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )          0.106519E+07    0.106519E+07   -0.371779E-05
      MASS(KG/DAY  )           516314.         516332.       -0.348801E-04
      ENTHALPY(KW      )       -87864.4        -87865.8        0.163260E-04

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  WASH2    MODEL: MIXER
-----------------------------
  INLET STREAMS:          AASPROD     AASWAT
  OUTLET STREAM:          SACHIN
  PROPERTY OPTION SET:    RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           905971.         905971.         0.00000
      MASS(KG/DAY  )           399133.         399133.         0.437505E-15
      ENTHALPY(KW      )       -71958.8        -71958.8       -0.404451E-15

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  WASH3    MODEL: MIXER
-----------------------------
  INLET STREAM:           9
  OUTLET STREAM:          11
  PROPERTY OPTION SET:    RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE

                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           8084.44         8084.44         0.00000
      MASS(KG/DAY  )           12202.5         12202.5         0.00000
      ENTHALPY(KW      )       -1229.61        -1229.61        0.00000

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                         ***  INPUT DATA  ***
  TWO    PHASE      FLASH
  MAXIMUM NO. ITERATIONS                                  30
  CONVERGENCE TOLERANCE                                    0.000100000
  OUTLET PRESSURE:  MINIMUM OF INLET STREAM PRESSURES

BLOCK:  WATPUR   MODEL: DECANTER
--------------------------------
  INLET STREAM:           STOUT
  FIRST LIQUID OUTLET:    WATER1
  SECOND LIQUID OUTLET:   ETHOUT2
  PROPERTY OPTION SET:    RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE


    ***********************************************************************
    *                                                                     *
    *     VAPOR PRESENT IN FEED TO BLOCK                                  *
    *                                                                     *
    ***********************************************************************


                     ***  MASS AND ENERGY BALANCE  ***
                                  IN              OUT        RELATIVE DIFF.
   TOTAL BALANCE
      MOLE(MOL/HR  )           6683.33         6683.33       -0.272168E-15
      MASS(KG/DAY  )           3775.64         3775.64       -0.125225E-06
      ENTHALPY(KW      )       -497.680        -506.261        0.169487E-01

                     ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    71.4381      KG/DAY
   TOTAL CO2E PRODUCTION        71.4381      KG/DAY

                         ***  INPUT DATA  ***

  LIQUID-LIQUID SPLIT, TP SPECIFICATION
  SPECIFIED TEMPERATURE             C                         90.0000
  SPECIFIED PRESSURE                ATM                        1.00000
  CONVERGENCE TOLERANCE ON EQUILIBRIUM                         0.10000
  MAXIMUM NO ITERATIONS ON EQUILIBRIUM                         50
  EQUILIBRIUM METHOD                             EQUATION-SOLVING
  KLL COEFFICIENTS FROM                          OPTION SET OR EOS
  KLL BASIS                                                  MOLE
  KEY COMPONENT(S):       DIETHER

                          ***  RESULTS  ***

  OUTLET TEMPERATURE      C                                   90.000
  OUTLET PRESSURE         ATM                                 1.0000
  CALCULATED HEAT DUTY    KW                                 -8.5805
  MOLAR RATIO 1ST LIQUID / TOTAL LIQUID                       0.95697

  L1-L2 PHASE EQUILIBRIUM :
     COMP         F             X1            X2            K
     WATER     0.96371       1.00000       0.15650       0.15650
     GLUCOSE   0.870177-06   0.908845-06   0.101279-07   0.011144
```

```
   DIETHER    0.036292      0.169874-08   0.84350       0.496545+09

                    ***  ASSOCIATED  UTILITIES  ***

 UTILITY ID FOR ELECTRICITY                  ELEC
 RATE OF CONSUMPTION                       8.5805  KW
 COST                                      0.6650  $/HR
 CO2 EQUIVALENT EMISSIONS                 71.4381  KG/DAY

BLOCK:  XLAFERM  MODEL: RYIELD
------------------------------
  INLET STREAM:          S23
  OUTLET STREAM:         3
  PROPERTY OPTION SET:   RK-ASPEN  REDLICH-KWONG-ASPEN EQUATION OF STATE


    *********************************************************************
    *                                                                   *
    *     SPECIFIED YIELDS HAVE BEEN NORMALIZED TO MAINTAIN MASS BALANCE  *
    *                                                                   *
    *********************************************************************


                   ***  MASS AND ENERGY BALANCE  ***
                           IN          OUT       GENERATION   RELATIVE DIFF.
  TOTAL BALANCE
  MOLE(MOL/HR  )         368101.       369331.       1229.13     -0.315206E-15
  MASS(KG/DAY  )         175104.       175104.                     0.00000
  ENTHALPY(KW      )    -30424.4      -30418.2                   -0.203185E-03

                   ***  CO2 EQUIVALENT SUMMARY ***
   FEED STREAMS CO2E            0.00000      KG/DAY
   PRODUCT STREAMS CO2E         0.00000      KG/DAY
   NET STREAMS CO2E PRODUCTION  0.00000      KG/DAY
   UTILITIES CO2E PRODUCTION    0.00000      KG/DAY
   TOTAL CO2E PRODUCTION        0.00000      KG/DAY

                       ***  INPUT DATA  ***
  TWO    PHASE  TP  FLASH
  SPECIFIED TEMPERATURE C                                  32.0000
  SPECIFIED PRESSURE    ATM                                 1.00000
  MAXIMUM NO. ITERATIONS                                   30
  CONVERGENCE TOLERANCE                                     0.000100000

   MASS-YIELD
    SUBSTREAM MIXED   :
    XYLOSE    0.132        OTHSOLID  0.100        ENZ/XYL   0.868

  INERTS:        WATER      OTHLIQUI

                        ***  RESULTS  ***
  OUTLET TEMPERATURE    C                                   32.000
  OUTLET PRESSURE       ATM                                 1.0000
  HEAT DUTY             KW                                  6.1818
  VAPOR FRACTION                                            0.0000


  V-L PHASE EQUILIBRIUM :

     COMP             F(I)           X(I)           Y(I)           K(I)
     WATER          0.81774        0.81774        0.84177        0.36429E-01
     XYLOSE         0.13233E-02    0.13233E-02    0.10967E-08    0.29330E-07
     OTHLIQUI       0.16788        0.16788        0.15786        0.33278E-01
     OTHSOLID       0.44383E-02    0.44383E-02    0.36749E-03    0.29303E-02
     ENZ/XYL        0.86166E-02    0.86166E-02    0.21456E-07    0.88122E-07
```

# *Utility Report*

```
UTILITY USAGE:  AIR       (GENERAL)
-----------------------------------

AIR, INLET TEMP=30 C, OUTLET TEMP=35 C
 INPUT DATA:

   INLET TEMPERATURE                   30.0000  C
   OUTLET TEMPERATURE                  35.0000  C
   HEAT TRANSFER COEFFICIENT         2.6512-03  CAL/SEC-SQCM-K
   COOLING VALUE                     5000.0000  J/KG
   PRICE                                0.0     $/CAL
   INDEX TYPE                             FUEL

 RESULT:

   COOLING VALUE                     5000.0000  J/KG
   INDEXED PRICE                        0.0     $/CAL

 THIS UTILITY IS PURCHASED

 USAGE:

 BLOCK ID  MODEL         DUTY              USAGE RATE       COST
                         KW                KG/DAY           $/HR
 --------  ------------  ----------------  ---------------- ----------------
 ETHFLASH  FLASH2               27.7031         4.7871+05            0.0
                         ----------------  ---------------- ----------------
                TOTAL:          27.7031         4.7871+05            0.0
                         ================  ================ ================


UTILITY USAGE:  COOLINGW  (WATER)
---------------------------------

COOLING WATER, INLET TEMP=20 C, OUTLET TEMP=25 C
 INPUT DATA:

   INLET TEMPERATURE                   20.0000  C
   OUTLET TEMPERATURE                  25.0000  C
   INLET PRESSURE                       1.0000  ATM
   OUTLET PRESSURE                      1.0000  ATM
   HEAT TRANSFER COEFFICIENT         8.9567-02  CAL/SEC-SQCM-K
   PRICE                             8.8760-10  $/CAL
   INDEX TYPE                             FUEL

 RESULT:

   COOLING VALUE                     2.0876+04  J/KG
   INDEXED PRICE                     8.8760-10  $/CAL

 THIS UTILITY IS PURCHASED

 USAGE:
```

```
 BLOCK ID  MODEL         DUTY              USAGE RATE        COST
                         KW                KG/DAY            $/HR
 --------  ------------  ----------------  ----------------  ----------------
 B13       HEATER               3621.9970        1.4991+07            2.7643
 DRYPLA    FLASH2                 13.5046        5.5893+04        1.0307-02
 CAOH-NEU  RSTOIC                745.5137        3.0855+06            0.5690
 AAS       RYIELD               1988.7642        8.2310+06            1.5178
                         ----------------  ----------------  ----------------
               TOTAL:           6369.7795        2.6363+07            4.8614
                         ================  ================  ================


UTILITY USAGE:  ELEC      (ELECTRICITY)
---------------------------------------

ELECTRICAL UTILITY
 INPUT DATA:

   CO2 DATA SOURCE                         US-EPA-RULE-E9-5711
   CO2 FUEL SOURCE                         NATURAL_GAS
   CO2 EMISSION FACTOR               2.3400-07  KG/CAL
   THERMAL EFFICIENCY                   0.5800
   PRICE                             7.7500-02  $/KWHR
   INDEX TYPE                             FUEL

 RESULT:

   INDEXED PRICE                     7.7500-02  $/KWHR
   CO2 EMISSION FACTOR               2.3400-07  KG/CAL
   TOTAL CO2 EMISSIONS               1.1319+04  KG/DAY

 THIS UTILITY IS PURCHASED

 USAGE:

 BLOCK ID  MODEL         DUTY              USAGE RATE        COST              CO2E
EMISSIONS
                         KW                KW                $/HR              KG/DAY
 --------  ------------  ----------------  ----------------  ----------------  ---------
-------
 EVAP2     FLASH2               1359.5488        1359.5488          105.3650
1.1319+04
                         ----------------  ----------------  ----------------  ---------
-------
               TOTAL:           1359.5488        1359.5488          105.3650
1.1319+04
                         ================  ================  ================
================


UTILITY USAGE:  FURNACE   (GENERAL)
-----------------------------------

FIRED HEATER, INLET TEMP=1000 C, OUTLET TEMP=400 C
 INPUT DATA:

   INLET TEMPERATURE                 1000.0000  C
   OUTLET TEMPERATURE                 400.0000  C
   HEAT TRANSFER COEFFICIENT         2.6512-03  CAL/SEC-SQCM-K
   CO2 DATA SOURCE                         US-EPA-RULE-E9-5711
   CO2 FUEL SOURCE                         NATURAL_GAS
   CO2 EMISSION FACTOR               2.3400-07  KG/CAL
   THERMAL EFFICIENCY                   0.8500
   HEATING VALUE                     6.0000+05  J/KG
   PRICE                             1.7794-08  $/CAL
   INDEX TYPE                             FUEL
```

```
 RESULT:

   HEATING VALUE                     6.0000+05  J/KG
   INDEXED PRICE                     1.7794-08  $/CAL
   CO2 EMISSION FACTOR               2.3400-07  KG/CAL
   TOTAL CO2 EMISSIONS                459.6242  KG/DAY

 THIS UTILITY IS PURCHASED

 USAGE:

 BLOCK ID  MODEL         DUTY              USAGE RATE        COST              CO2E
EMISSIONS
                         KW                KG/DAY            $/HR              KG/DAY
 --------  ------------  ----------------  ----------------  ----------------  ---------
-------
 B17       HEATER                 80.9048        1.1650+04            1.2378
459.6242
                         ----------------  ----------------  ----------------  ---------
-------
               TOTAL:              80.9048        1.1650+04            1.2378
459.6242
                         ================  ================  ================
================


UTILITY USAGE:  HPSTEAM   (STEAM)
---------------------------------

HIGH PRESSURE STEAM, INLET TEMP=250 C, OUTLET TEMP=249 C, PRES=572 PSIA
 INPUT DATA:

   INLET TEMPERATURE                  250.0000  C
   OUTLET TEMPERATURE                 249.0000  C
   INLET VAPOR FRACTION                 1.0000
   OUTLET VAPOR FRACTION                0.0
   HEAT TRANSFER COEFFICIENT            0.1433  CAL/SEC-SQCM-K
   CO2 DATA SOURCE                         US-EPA-RULE-E9-5711
   CO2 FUEL SOURCE                         NATURAL_GAS
   CO2 EMISSION FACTOR               2.3400-07  KG/CAL
   THERMAL EFFICIENCY                   0.8500
   PRICE                             1.0467-08  $/CAL
   INDEX TYPE                             FUEL

 RESULT:

   HEATING VALUE                     1.7193+06  J/KG
   INDEXED PRICE                     1.0467-08  $/CAL
   CO2 EMISSION FACTOR               2.3400-07  KG/CAL
   TOTAL CO2 EMISSIONS               4640.0210  KG/DAY

 THIS UTILITY IS PURCHASED

 USAGE:

 BLOCK ID  MODEL         DUTY              USAGE RATE        COST              CO2E
EMISSIONS
                         KW                KG/DAY            $/HR              KG/DAY
 --------  ------------  ----------------  ----------------  ----------------  ---------
-------
 POLYREAC  RSTOIC                816.7544        4.1044+04            7.3508
4640.0210
                         ----------------  ----------------  ----------------  ---------
-------
```

| | | DUTY | USAGE RATE | COST | CO2E EMISSIONS |
|---|---|---|---|---|---|
| | TOTAL: | 816.7544 | 4.1044+04 | 7.3508 | 4640.0210 |

UTILITY USAGE: LPSTEAM (STEAM)

LOW PRESSURE STEAM, INLET TEMP=125 C, OUTLET TEMP=124 C

INPUT DATA:

| | | |
|---|---|---|
| INLET TEMPERATURE | 125.0000 | C |
| OUTLET TEMPERATURE | 124.0000 | C |
| INLET VAPOR FRACTION | 1.0000 | |
| OUTLET VAPOR FRACTION | 0.0 | |
| HEAT TRANSFER COEFFICIENT | 0.1433 | CAL/SEC-SQCM-K |
| CO2 DATA SOURCE | US-EPA-RULE-E9-5711 | |
| CO2 FUEL SOURCE | NATURAL_GAS | |
| CO2 EMISSION FACTOR | 2.3400-07 | KG/CAL |
| THERMAL EFFICIENCY | 0.8500 | |
| PRICE | 7.9549-09 | $/CAL |
| INDEX TYPE | FUEL | |

RESULT:

| | | |
|---|---|---|
| HEATING VALUE | 2.1919+06 | J/KG |
| INDEXED PRICE | 7.9549-09 | $/CAL |
| CO2 EMISSION FACTOR | 2.3400-07 | KG/CAL |
| TOTAL CO2 EMISSIONS | 7.0094+31 | KG/DAY |

THIS UTILITY IS PURCHASED

USAGE:

| BLOCK ID | MODEL | DUTY KW | USAGE RATE KG/DAY | COST $/HR | CO2E EMISSIONS KG/DAY |
|---|---|---|---|---|---|
| B4 | SEP | 1.2338+31 | 4.8635+32 | 8.4394+28 | 7.0094+31 |
| B9 | SEP | 8.9875-03 | 0.3543 | 6.1474-05 | 5.1058-02 |
| B15 | HEATER | 242.8061 | 9570.9890 | 1.6608 | 1379.3933 |
| B16 | HEATER | 43.5867 | 1718.1100 | 0.2981 | 247.6180 |
| EVAP | FLASH2 | 3798.6169 | 1.4973+05 | 25.9825 | 2.1580+04 |
| | TOTAL: | 1.2338+31 | 4.8635+32 | 8.4394+28 | 7.0094+31 |

UTILITY USAGE: MPSTEAM (STEAM)

MEDIUM PRESSURE STEAM, INLET TEMP=175 C, OUTLET TEMP=174 C, PRES=127 PSIA

INPUT DATA:

| | | |
|---|---|---|
| INLET TEMPERATURE | 175.0000 | C |
| OUTLET TEMPERATURE | 174.0000 | C |
| INLET VAPOR FRACTION | 1.0000 | |
| OUTLET VAPOR FRACTION | 0.0 | |
| HEAT TRANSFER COEFFICIENT | 0.1433 | CAL/SEC-SQCM-K |
| CO2 DATA SOURCE | US-EPA-RULE-E9-5711 | |
| CO2 FUEL SOURCE | NATURAL_GAS | |
| CO2 EMISSION FACTOR | 2.3400-07 | KG/CAL |
| THERMAL EFFICIENCY | 0.8500 | |
| PRICE | 9.2110-09 | $/CAL |
| INDEX TYPE | FUEL | |

RESULT:

| | | |
|---|---|---|
| HEATING VALUE | 2.0348+06 | J/KG |
| INDEXED PRICE | 9.2110-09 | $/CAL |
| CO2 EMISSION FACTOR | 2.3400-07 | KG/CAL |
| TOTAL CO2 EMISSIONS | 744.8885 | KG/DAY |

THIS UTILITY IS PURCHASED

USAGE:

| BLOCK ID | MODEL | DUTY KW | USAGE RATE KG/DAY | COST $/HR | CO2E EMISSIONS KG/DAY |
|---|---|---|---|---|---|
| B1 | HEATER | 131.1182 | 5567.5632 | 1.0385 | 744.8885 |
| | TOTAL: | 131.1182 | 5567.5632 | 1.0385 | 744.8885 |

UTILITY USAGE: NONCONDS (STEAM)

MEDIUM PRESSURE STEAM, INLET TEMP=175 C, OUTLET TEMP=174 C, PRES=127 PSIA

INPUT DATA:

| | | |
|---|---|---|
| INLET TEMPERATURE | 175.0000 | C |
| OUTLET TEMPERATURE | 150.0000 | C |
| INLET VAPOR FRACTION | 1.0000 | |
| OUTLET VAPOR FRACTION | 0.5000 | |
| HEAT TRANSFER COEFFICIENT | 0.1433 | CAL/SEC-SQCM-K |
| CO2 DATA SOURCE | US-EPA-RULE-E9-5711 | |
| CO2 FUEL SOURCE | NATURAL_GAS | |
| CO2 EMISSION FACTOR | 2.3400-07 | KG/CAL |
| THERMAL EFFICIENCY | 0.8500 | |
| PRICE | 9.2110-09 | $/CAL |
| INDEX TYPE | FUEL | |

RESULT:

| | | |
|---|---|---|
| HEATING VALUE | 1.0828+06 | J/KG |
| INDEXED PRICE | 9.2110-09 | $/CAL |
| CO2 EMISSION FACTOR | 2.3400-07 | KG/CAL |
| TOTAL CO2 EMISSIONS | 536.4440 | KG/DAY |

THIS UTILITY IS PURCHASED

USAGE:

```
  BLOCK ID  MODEL         DUTY             USAGE RATE       COST             CO2E
EMISSIONS
                          KW               KG/DAY           $/HR             KG/DAY
  --------  ------------  ---------------- ---------------- ---------------- ---------
-------
  POLYHEAT  HEATER                94.4269        7534.8920           0.7479
536.4440
                          ---------------- ---------------- ---------------- ---------
-------
                TOTAL:            94.4269        7534.8920           0.7479
536.4440
                          ================ ================ ================
================


 UTILITY USAGE:  REFRIDGE  (REFRIGERANT)
 ---------------------------------------

 REFRIGERANT 1, INLET TEMP=-25 C, OUTLET TEMP=-24 C
  INPUT DATA:

    INLET TEMPERATURE                  -25.0000  C
    OUTLET TEMPERATURE                 -24.0000  C
    HEAT TRANSFER COEFFICIENT         3.1050-02  CAL/SEC-SQCM-K
    CO2 DATA SOURCE                         US-EPA-RULE-E9-5711
    CO2 FUEL SOURCE                         NATURAL_GAS
    CO2 EMISSION FACTOR               2.3400-07  KG/CAL
    THERMAL EFFICIENCY                   1.0000
    COOLING VALUE                     4000.0000  J/KG
    PRICE                             1.1472-08  $/CAL
    INDEX TYPE                             FUEL

  RESULT:

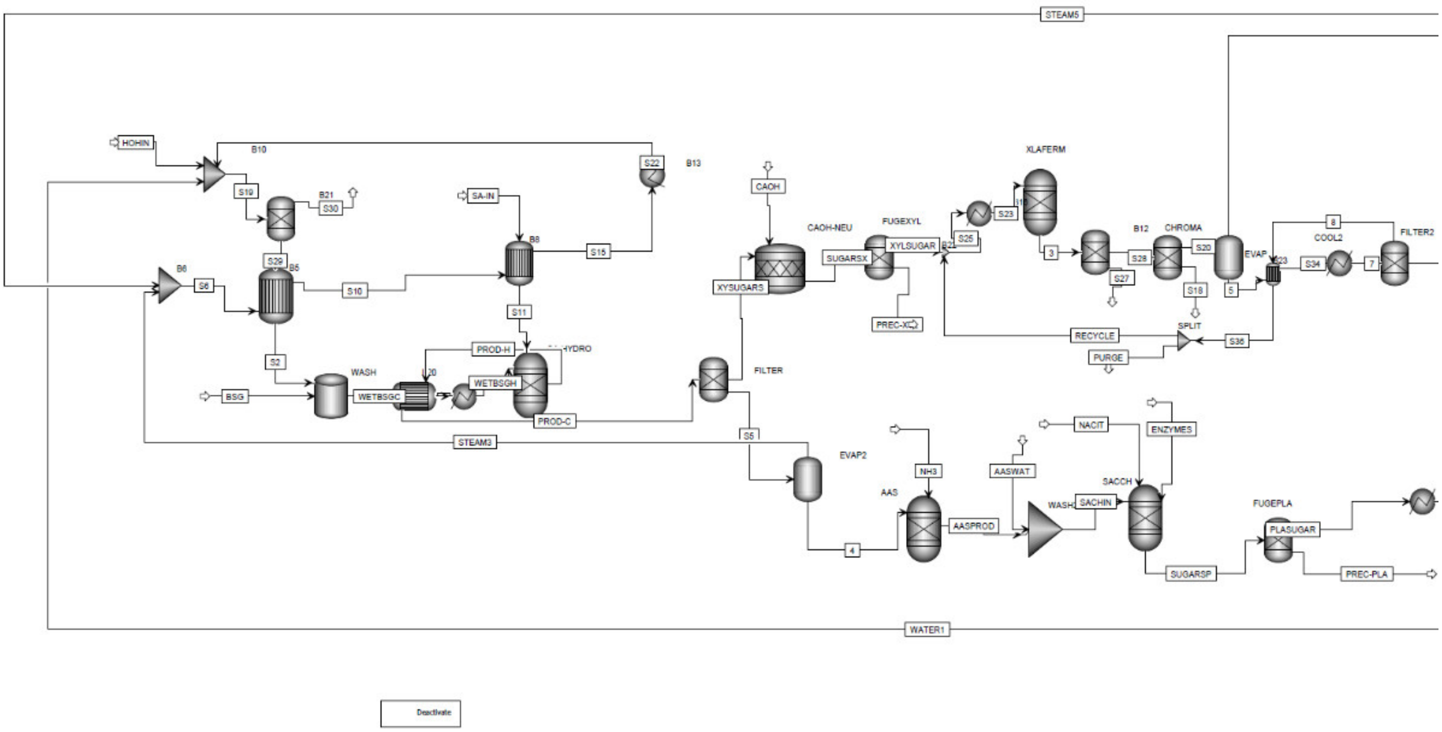
    COOLING VALUE                     4000.0000  J/KG
    INDEXED PRICE                     1.1472-08  $/CAL
    CO2 EMISSION FACTOR               2.3400-07  KG/CAL
    TOTAL CO2 EMISSIONS                179.5814  KG/DAY

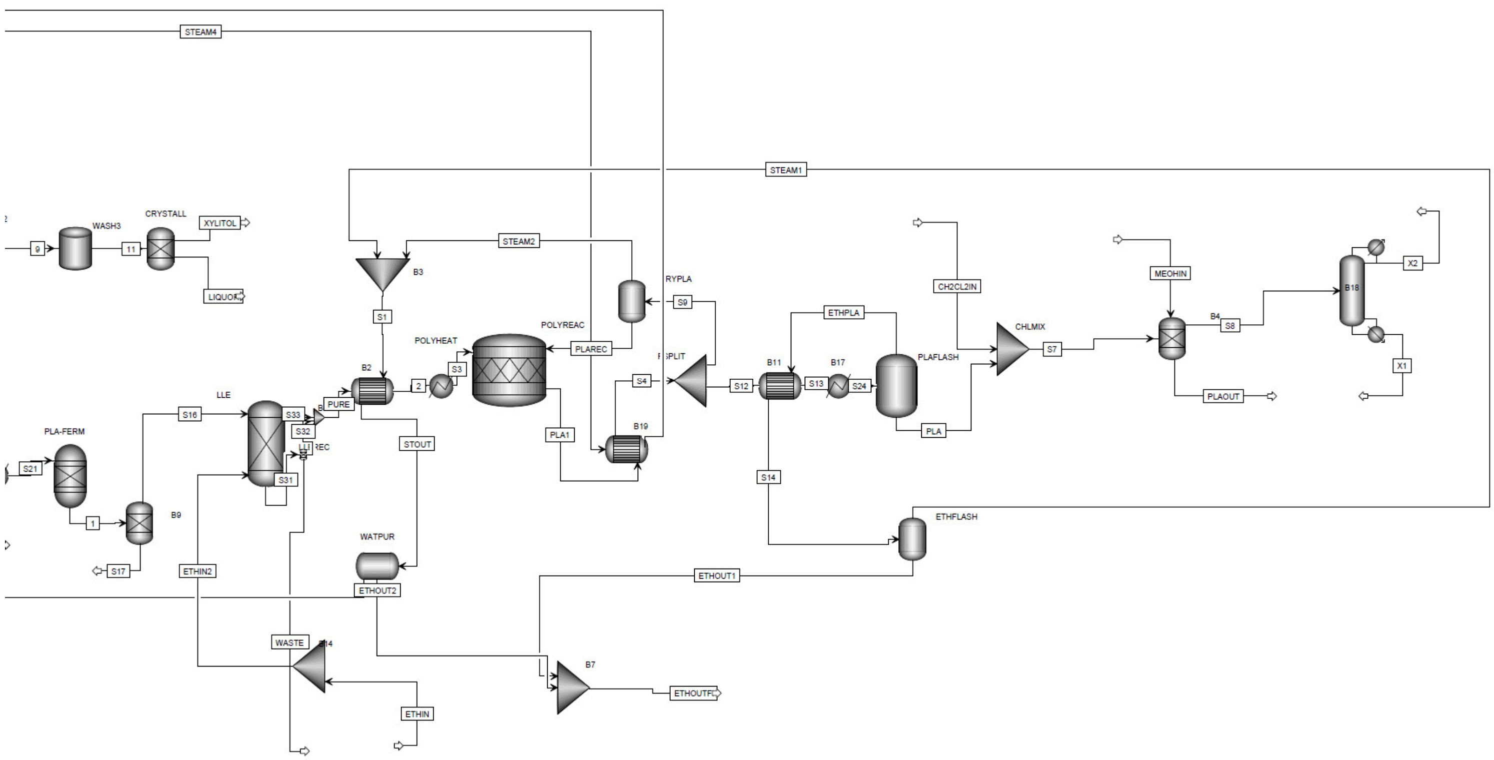
  THIS UTILITY IS PURCHASED

  USAGE:

  BLOCK ID  MODEL         DUTY             USAGE RATE       COST             CO2E
EMISSIONS
                          KW               KG/DAY           $/HR             KG/DAY
  --------  ------------  ---------------- ---------------- ---------------- ---------
-------
  COOL2     HEATER                37.1890       8.0328+05            0.3668
179.5814
                          ---------------- ---------------- ---------------- ---------
-------
                TOTAL:            37.1890       8.0328+05            0.3668
179.5814
                          ================ ================ ================
```

# Appendix A4 – Aspen Process Flowsheet





STEAM4
STEAM1
WASH3
CRYSTALL
XYLITOL
LIQUOR
STEAM2
B3
RYPLA
S9
S1
POLYREAC
POLYHEAT
PLAREC
S3
B2
S4
PSPLIT
S12
B11
S13
B17
S24
ETHPLA
PLAFLASH
PLA
CH2CL2IN
CHLMIX
S7
MEOHIN
B4
S8
B18
X2
X1
PLAOUT
LLE
S16
S33
PURE
S32
S31
PLA-FERM
S21
B9
S17
PLA1
B19
STOUT
S14
ETHFLASH
WATPUR
ETHOUT2
ETHOUT1
ETHIN2
WASTE
B7
ETHIN

# Appendix A5 – Xylitol Quality Sheet

华康药业 HUAKANG PHARMA

*The specialized manufacture in functional polyols*

## Specifications and Quality Standards of Xylitol

| Identification \ Grade | FCC | USP | JP | BP/EP | E967 |
|---|---|---|---|---|---|
| Assay % | 98.5-101.0 | 98.5-101.0 | ≥98.0 | 98.0-102.0 | ≥98.5 |
| Other Polyols % | ≤1.0 | ≤2.0 | - | ≤2.0 (Related Substances) | ≤1.0 |
| Lossg on Drying % | ≤0.5 (Water) | ≤0.5 (Water) | ≤1.0 | ≤1.0(Water) | ≤0.5 |
| Residue on Ignition % | ≤0.1 | ≤0.5 | ≤0.1 | - | ≤0.1 (Sulphated ash) |
| Reducing Sugar % | ≤0.3 | ≤0.2 | To pass test(Sugar) | ≤0.2 | ≤0.2 |
| Heavy Metal(asPb) % | - | ≤0.001 | ≤0.0005 | - | ≤0.001 |
| Nickel % | ≤0.0001 | - | To pass test | ≤0.0001 | ≤0.0002 |
| Lead % | ≤0.0001 | - | - | ≤0.00005 | ≤0.0001 |
| Acidity or Alkalinity | - | - | - | - | - |
| pH | - | - | 5.0-7.0 | - | 5.0-7.0 |
| Sulfate(as SO4) % | - | - | ≤0.006 | - | ≤0.02 |
| Chloride % | - | - | ≤0.005 | - | ≤0.01 |
| Arsenic (as As2O3) % | - | - | ≤0.00013 | - | ≤0.0003 |
| Melting Range °C | - | - | 93.0-95.0 | 92-96 | 92-96 |
| Conductivity \|is/cm | - | - | - | ≤20 | - |
| Identification Test | To pass test | To pass test | To pass test | Pass A, B and C | - |
| Bacterial Endotoxins I.U./g | - | - | - | ≤2.5lu(≥100g/l) ≤4.0lu(≤100g/l) | - |
| Bacterial and Funji cfu/g | - | - | - | - | - |
| Escherichia Coli | - | - | - | - | - |
| Salmonella | - | - | - | - | - |
| Organic Volatile Impurities | - | Meets the requirement | - | - | - |
| Residual solvents | - | Meets the requirement | - | - | - |
| Consult Standard | FCC V | USP29 | JP X IV | BP2005 / EP5 | E967 |

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**http** // www.huachem.com

# Appendix A6 – Sample Equations

I. **Physical and Chemical Equations**

1. **pH Calculation**

$$\boldsymbol{pH = \quad log(\frac{mol\ H^{+}\ released}{mol\ acid\ added} \quad \frac{mol\ acid}{L})}$$

$$\boldsymbol{pH = \quad log\left(2\ {}^{mol\ H^{+}}\!/_{mol\ sulfuric\ acid} \quad .211M\ sulfuric\ acid\right)}$$

$$\boldsymbol{= 0.37}$$

2. **Fermentation Kinetic Equations**

A. **Solute Concentration** (when desired input solute concentration known)

$$\boldsymbol{S = S_i \quad \frac{X}{Y_{X/S}}}$$

$$S = 80\ {}^{g\ xylose}\!/_{L} \quad \frac{14\ {}^{g\ cells}\!/_{L}}{0.34\ {}^{g\ cells}\!/_{g\ xylose\ consumed}}$$

$$= 38.82\ {}^{g\ xylose}\!/_{L}$$

B. **Input Solute Concentration** (when desired solute concentration known)

$$\boldsymbol{S_i = S + \frac{X}{Y_{X/S}}}$$

$$\boldsymbol{S_i = 50\ {}^{g\ glucose}\!/_{L} + \frac{2\ {}^{g\ cells}\!/_{L}}{0.059\ {}^{g\ cells}\!/_{g\ glucose\ consumed}}}$$

$$\boldsymbol{= 83.9\ {}^{g\ glucose}\!/_{L}}$$

C. **D$_{opt}$**

$$\boldsymbol{D_{opt} = \mu_{max}(1 \quad \sqrt{\frac{K_S}{K_S + S}})}$$

$$\boldsymbol{D_{opt} = 0.183h^{-1}\left(1 \quad \sqrt{\frac{13.11}{13.11 + 50}}\right) = 0.10h^{-1}}$$

D. **Heat of Fermentation**

$$\boldsymbol{Q_{GR} = \mu \quad X \quad \frac{1}{Y_H} \quad V}$$

$$\boldsymbol{Q_{GR} = (0.183h^{-1})\left(2\ {}^{g\ cells}\!/_{L}\right)\left(230.5\ {}^{kJ}\!/_{g\ cell}\right)(76{,}330L)}$$

$$\boldsymbol{= 6{,}4\ 394\ 62\ {}^{kJ}\!/_{h}}$$

E. **Product Concentration**

$$\boldsymbol{P = \frac{q_P \quad X}{D}}$$

$$P = \frac{\left(3.038 \, {}^{gP}\!/_{g\ cells \quad h}\right) \quad \left(2 \, {}^{g\ cells}\!/_{L}\right)}{0.1 h^{-1}} = 61 \, {}^{gP}\!/_{L}$$

## II. Financial Equations

### 1. Return on Investment

$$ROI = \frac{Net\ Earnings}{Total\ Capital\ Investment} x100$$

$$ROI = \frac{\$10{,}790{,}200}{\$42{,}378{,}200} x100 = \mathbf{25.5}\%$$

### 2. Internal Rate of Return

$$IRR = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} x100 = 30.95\%$$

Where $C_n$ is the cash flow at year N, and r is the calculated IRR